

Homestake DUSEL Project Overview

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UC Berkeley

Fermi Lab
24 June 2009

BIG BANG

possible dark matter relics

cosmic microwave radiation visible

t	10^{-44}	10^{-37} s
T	10^{32}	10^{28}
E	10^{19}	10^{15}

10^{-10} s	10^{-5} s	10^{-1} s	10^2 s	10^9 s	3×10^{10} y	10^9 y	10^{12} y	2.3×10^{12} y
10^{-15} s	10^{-12} s	10^{-9} s	10^{-6} s	10^{-3} s	3000 y	15 y	10^{-12} y	
10^{-2} s	10^2 s	10^5 s	10^8 s	10^{11} s	3×10^{10} y			

Practice Safety Always.
GENERAL NOTES
Insp. By _____
Rivets _____ Open Holes _____ Unless Noted
Height Dimension _____ Length Dimension _____
WORDEN-ALLEN CO.
MILWAUKEE, WIS.
Description _____
Location _____
Date _____
Drawn by _____
Checked by _____

Figure
Courtesy PDG

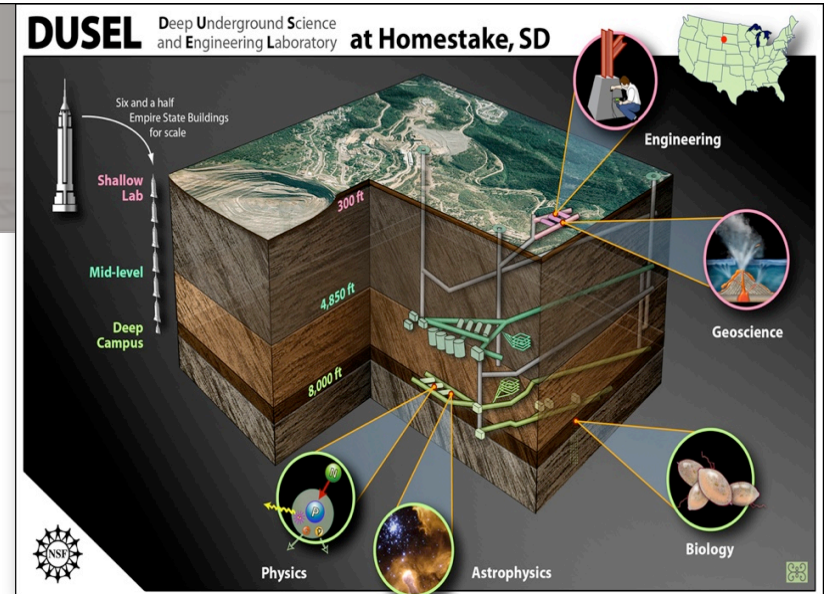
LONGSECTION OF THE HOMESTAKE MINE



Homestake DUSEL

Outline of Today's Presentation

- The DUSEL Project
 - Major Milestones
 - Key Facility Parameters
 - DUSEL's Conceptual Design
- Programs Aligned with Physics Long Range Plans
 - Long Baseline Neutrino Experiments
 - Dark Matter Searches
 - Neutrinoless Double Beta Decay
 - Nuclear Astrophysics
- Summary



We are Working to Establish a Proposal for DUSEL and its Integrated Suite of Experiments

LONGSECTION OF THE HOMESTAKE MINE

- In 2004 the National Science Foundation established a process to create a Deep Underground Science and Engineering Laboratory (DUSEL)
- The State of South Dakota strongly supports the efforts at Homestake
- Through a process of evaluations Homestake was selected in 2007
- In 2007 UC Berkeley (Lesko PI/director) was funded to advance designs and prepare a plan for the facility design phase and prepare an “integrated suite of experiments”
- World-class, Dedicated Multidisciplinary Underground Research Facility Providing
 - Environment, Health and Safety Functions
 - Research Space, Environment, and Support
 - Operations and Support Staff and Technical Experts
- Defining and Integrating a Suite of Experiments
 - Physics
 - Biology
 - Geosciences
 - Engineering
- Encouraging and Providing Key Facility Infrastructure Enabling Participation in addition to the NSF (and US)
- Integral Education and Outreach Programs

Why Underground Science?

DUSEL has been extensively addressed by the Scientific Communities, Agencies, National Academies:

- Bahcall Committee Report 2001
- Nuclear Physics Long Range Plan 2002
- Connecting Quarks to the Cosmos
- HEPAP Long Range Plan 2003
- Neutrinos and Beyond
- EarthLab
- Physics of the Universe
- The Neutrino Matrix
- Earth Scope
- Discovering the Quantum Universe
- Deep Science
- Nuclear Physics Long Range Plan 2007
- 2008 P5 Report

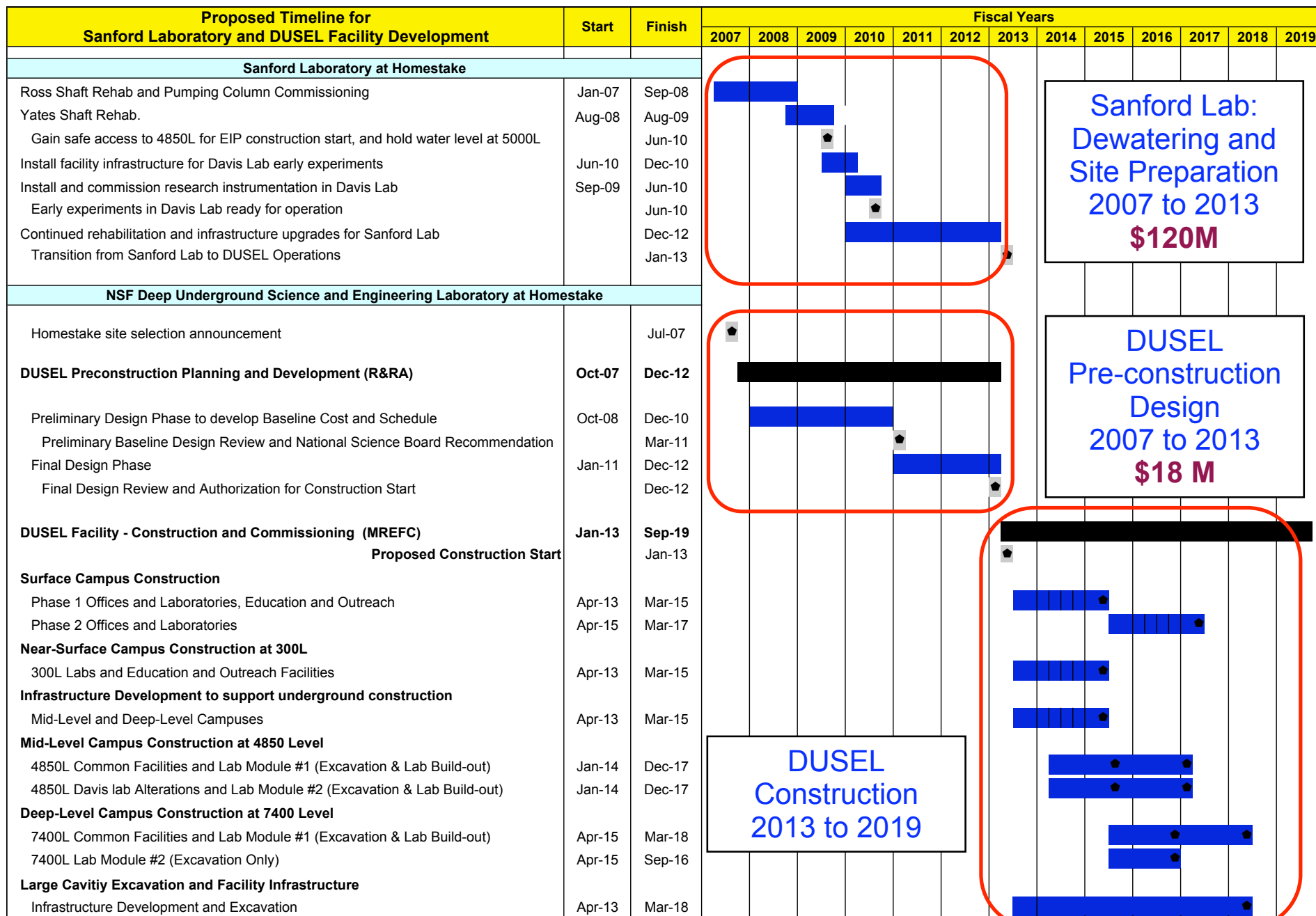


Why Are We Developing DUSEL?



To enable the Science, exploit synergisms, maximize the benefits of a dedicated facility, and integrate Education and Outreach functions

- Neutrinos - discover new physics, known-unknown physics
- Dark Matter - identify ~25% of the known-unknown universe
- Dark Life - limits of life, life in extremes, life in isolation, new life
- Origin of the Elements - how, where did the elements originate
- Symmetries and High Energy Scale Physics - matter/antimatter asymmetry, the universe at extreme energies and physics of the early universe
- Natural Resources - understanding, probing, predicting
- Engineering - safer, deeper, larger, faster
- Education and Outreach - welcome, attract, excite, engage
- Energy and Carbon Research - imperative societal questions

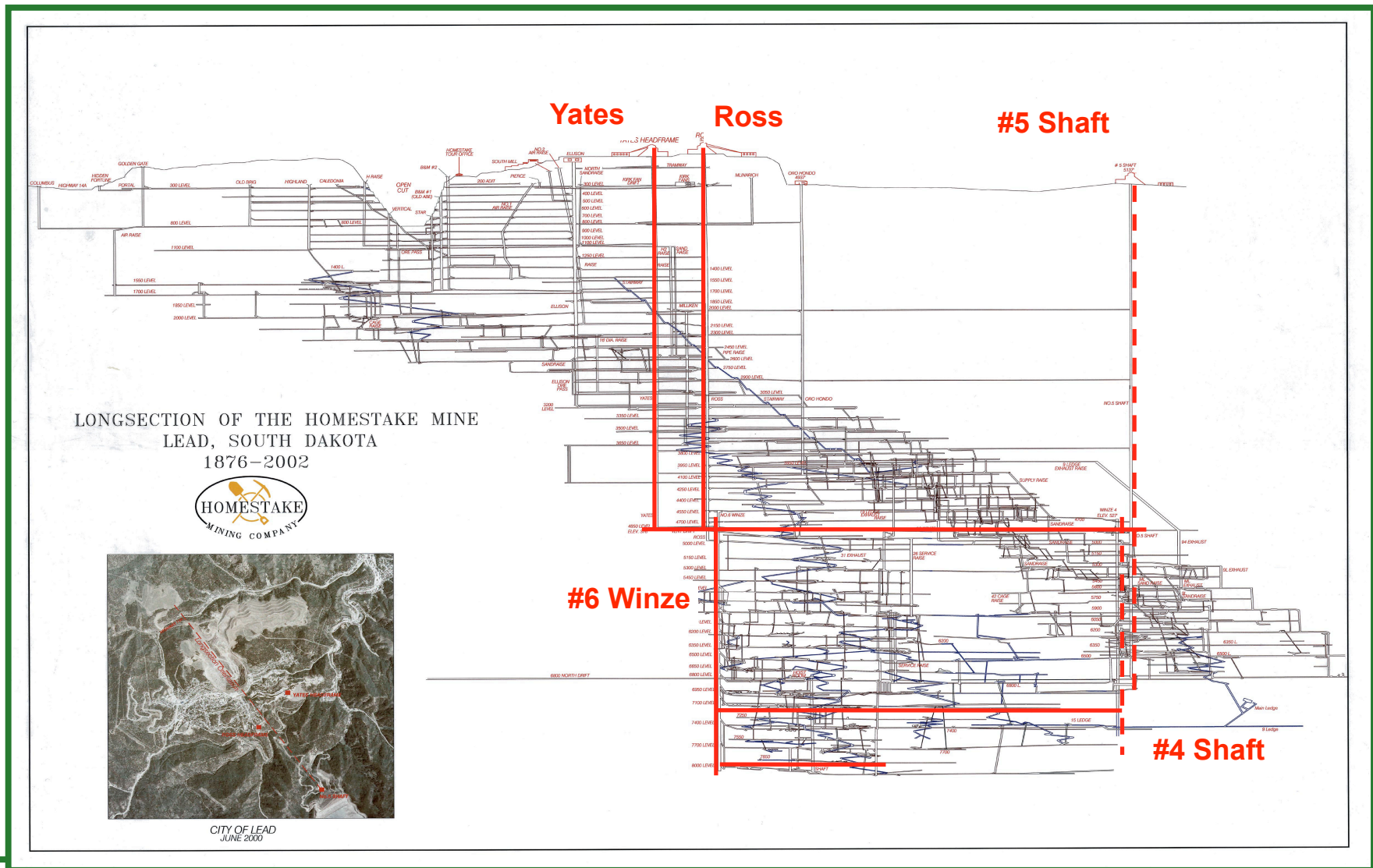


Major Milestones

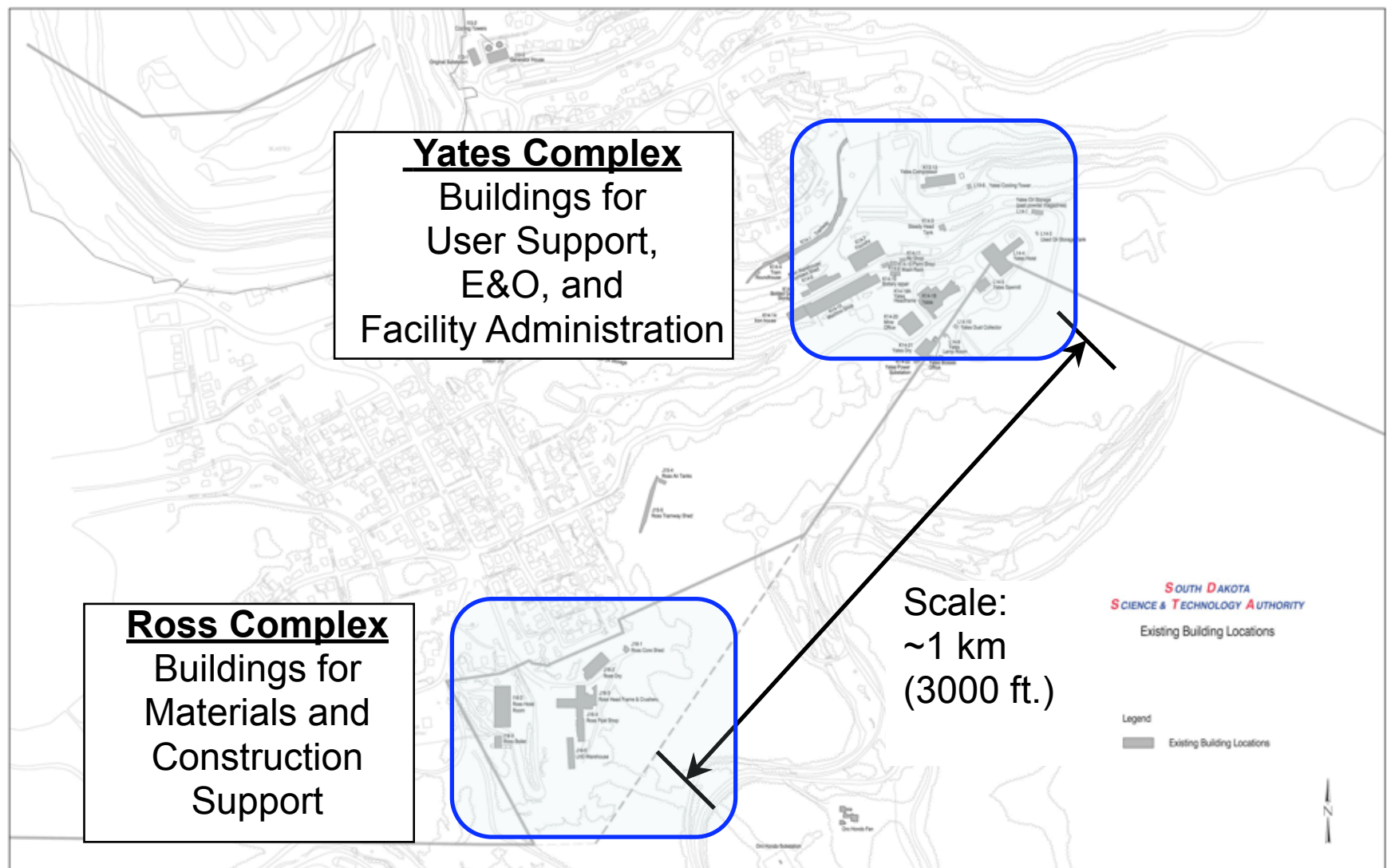
- Large Cavity Design Supplement **May 2009**
- Proposal to Prepare Preliminary Facility Design & Integrate the Suite of Experiments: **submitted 15 May 2009**
- NSF Solicitation to Develop Experiments (S-4) Results: **anticipated ~ July 2009**
- S-4 Work Shop in South Dakota: **1-5 Oct 2009**
- Preliminary Design Complete: **fall 2010**
- Presentation to NSB: **spring 2011**
- Construction Start: **2nd Quarter 2013**

Cross Section of the Homestake Facility

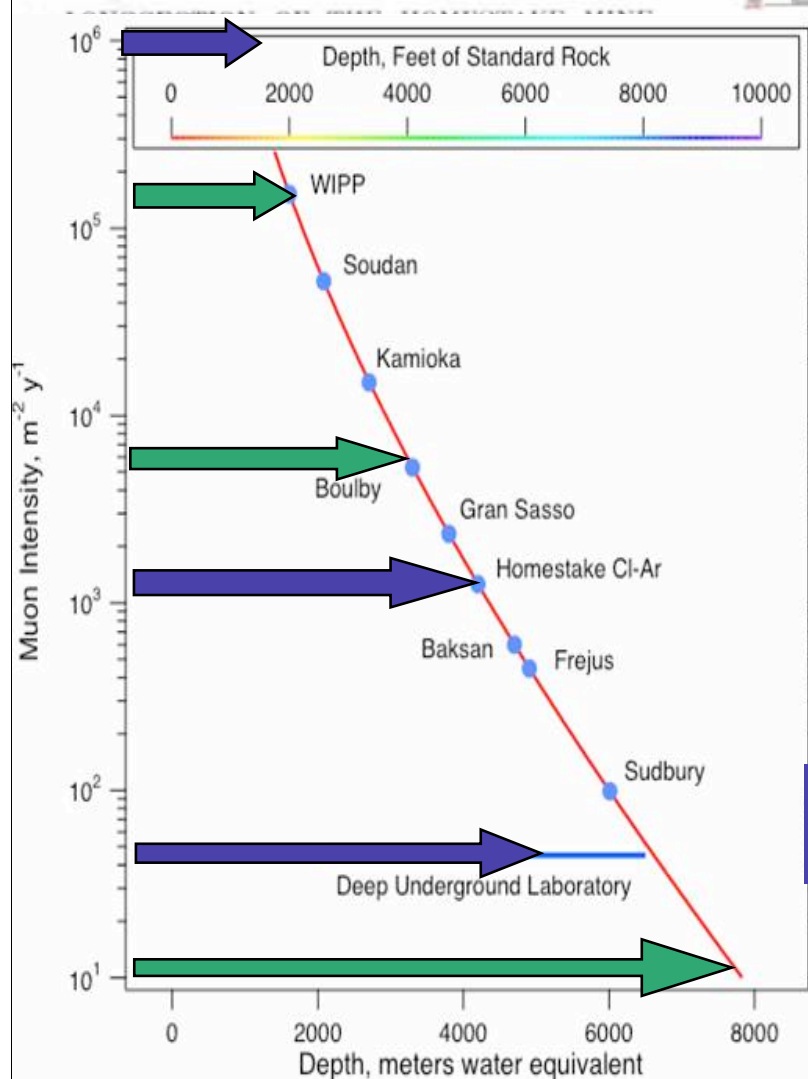
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Development of the Surface Campus will utilize existing structures, as feasible and cost-effective



Plans for Research Campuses Optimized for Science



300L R&D
E&O 10k ft²

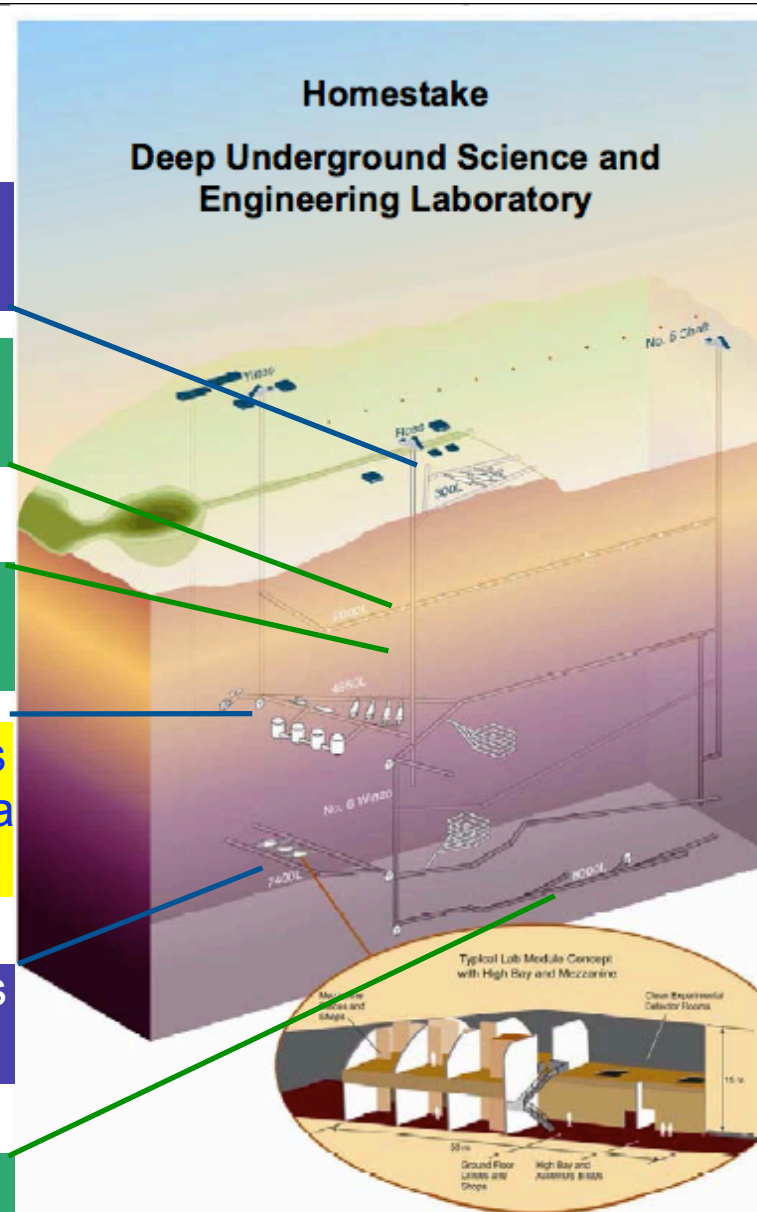
2000L BGE
Level

3800L BGE
Level

4850L Campus
100k ft² + Mega
Cavities

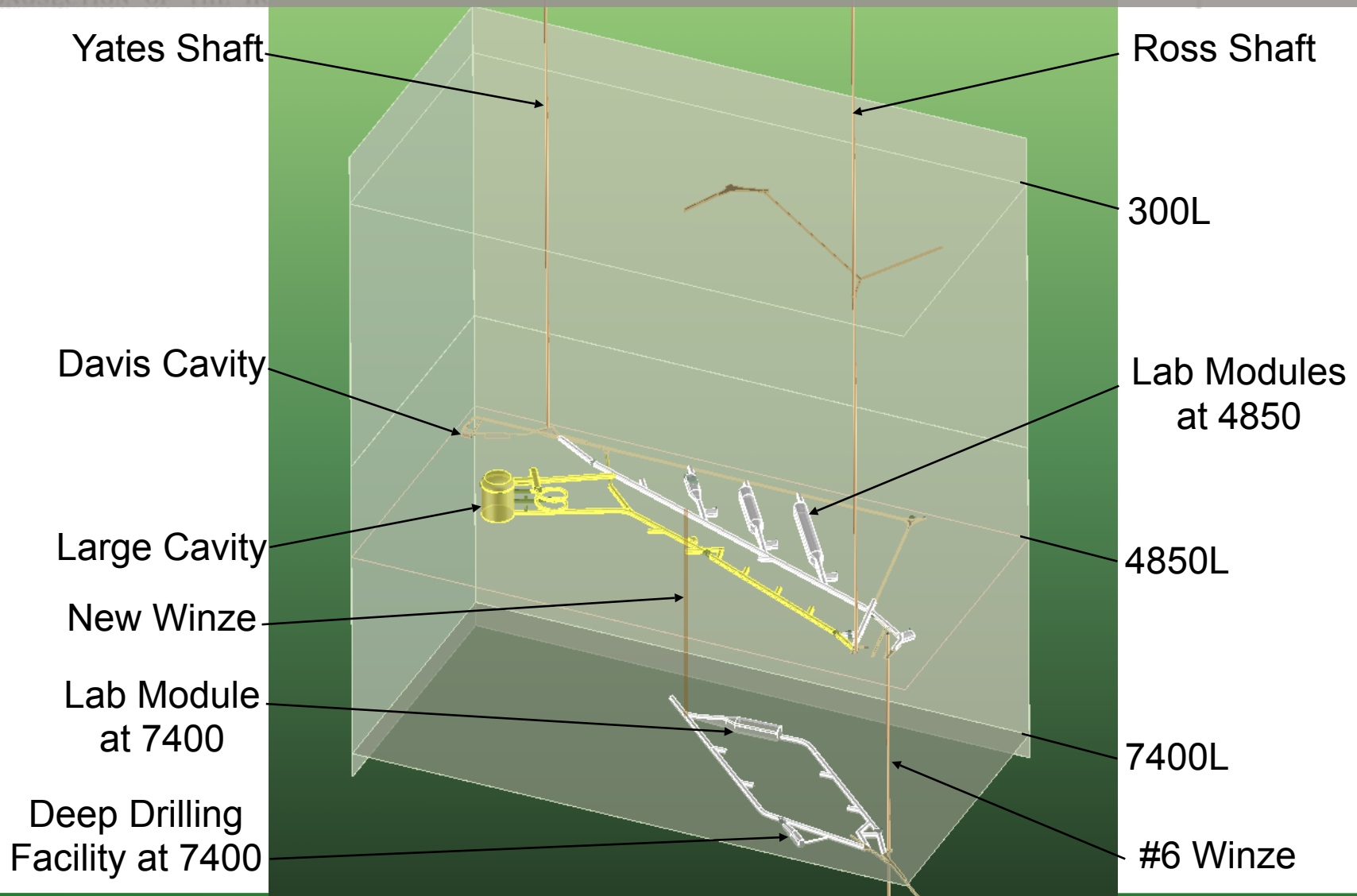
7400L Campus
65k ft²

8000L BGE
Lab

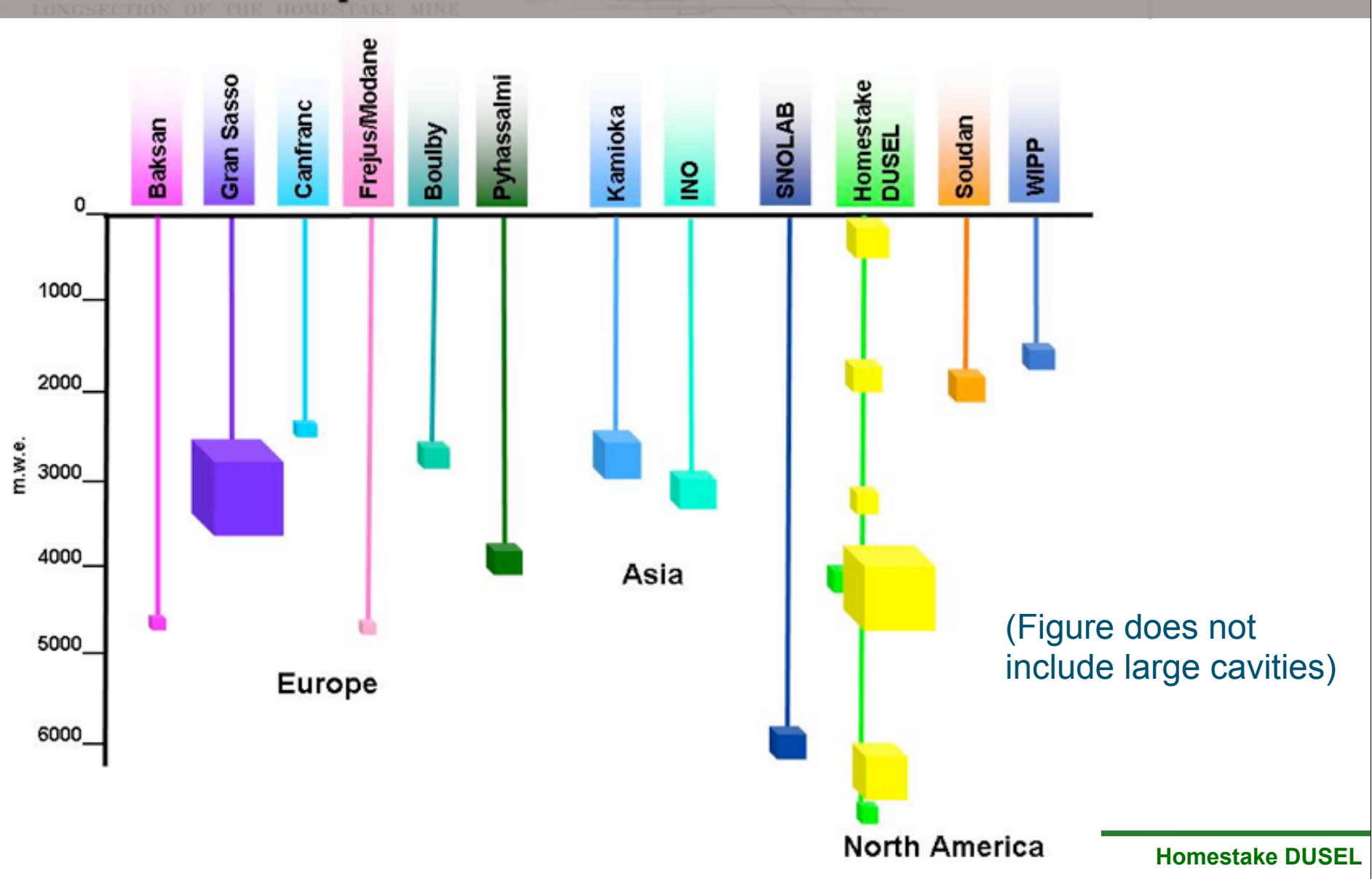


DUSEL Preliminary Underground Campus Development, MREFC Scope

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Providing Critical Research Space, Especially at Great Depths



Infrastructure, Facility, and Geotechnical Design/Site Assessment

- the Project is relying on three major design contracts for initial assessments
 - Surface Facility Assessment and Design - HDR
 - Underground Infrastructure Assessment and Design - ARUP
 - Geotechnical Site Assessments for Large Cavities and Lab Modules (4850L) - RESPEC
- All are on site
- Contract expansions and new contracts established as funds are available

Infrastructure, Facility, and Geotechnical Design/Site Assessment

- **Geotech Site Investigations**
 - 3D geological model developed
 - laser mapping of the 300L completed
 - 4100 to 4850L preliminary geological/structural mapping developed (addition work initiated)
 - coring and testings to initiate work on the 4850L in July
 - Lab Modules
 - preliminary siting & orientation
 - Large Cavity
 - Initial sites begin developed
 - geotechnical investigation campaign initiated

Infrastructure, Facility, and Geotechnical Design/Site Assessment

- **Surface Facility**
 - building assessments, documentation
 - infrastructure
 - power
 - sewers
 - water
 - IT
 - roads
 - security
 - ...
 - preliminary assessment being followed by preliminary design for upgrade and estimate

Infrastructure, Facility, and Geotechnical Design/Site Assessment

- **Underground Infrastructure Assessment**
 - hoists & motors
 - shafts
 - ventilation
 - ground conditions
 - utilities
 - life and fire-safety plans
 - level inspections and documentation
 - ground conditions
 - hazard assessments
 - mitigation plans drafted

Infrastructure, Facility, and Geotechnical Design/Site Assessment

- Following initial geotechnical siting and infrastructure assessments this summer
 - excavation design
 - lab modules 4850 (extrapolated to 7400)
 - large cavity
 - lab module and large cavity design and buildout
 - using current (initial) requirements
- Extensions to existing contracts and additional contracts being negotiated/developed
- Education and Outreach Design integrated into Surface and Underground efforts

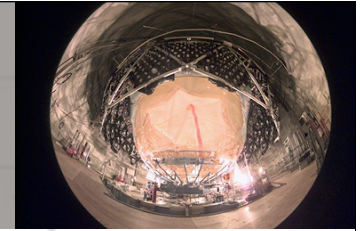
Infrastructure, Facility, and Geotechnical Design/Site Assessment

- **Safety Codes and Plans**
 - documentation developing
 - OSHA requirements and codes established
 - safety program in place
 - no lost-time injuries in 2009
 - significant increase in activity on the site
 - Emergency Response and Life Safety Programs in place, additional development for DUSEL required

Infrastructure, Facility, and Geotechnical Design/Site Assessment

- Environmental Impact Statement work initiated
 - ANL (environmental division) lead with NSF
 - draft schedule
 - NOI Summer 2009
 - Scoping meetings Summer 2009
 - Draft EIS Fall 2010
 - ROD Late 2011
 - first meetings occurred in Berkeley and Lead
 - Significant Cultural Outreach efforts continuing

DUSEL's Experimental Programs



- **DUSEL Experimental Development Committee (DEDC)**

- Steve Elliott, LANL **Physics**
- Derek Elsworth, PSU **Bio/Geo/Eng**
- Daniela Leitner, LBNL **Physics**
- Larry Murdoch, Clemson **Bio/Geo/Eng**
- T.C. Onstott, Princeton **Bio/Geo/Eng**
- Hank Sobel, UCI **Physics**

Promotes and aids the development of the Scientific Program, provides high-level coordination with facility team, actively working with collaborations on S-4

- **Project Scientists**

- Jason Detwiler, LBNL **DBD & DM Physics**
- Azriel Goldschmidt, LBNL **DBD & DM Physics**
- Richard Kadel, LBNL **Long Baseline Neutrinos**
- Bill Roggenthen, SDSM&T **Bio/Geo/Eng**
- Rohit Salve, LBNL **Bio/Geo/Eng**

Points of Contact for Science Collaborations to the Facility Design Team

- **Experimental Instrumentation Requirements Engineering**

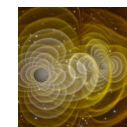
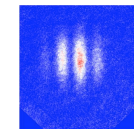
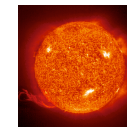
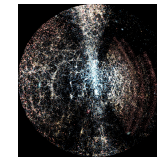
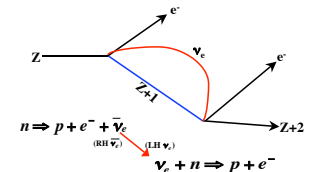
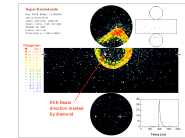
- Steve Marks, LBNL
- Dave Plate, LBNL

Develop Requirements Database, Model Experiments, And Laboratory Module Design

- **NSF, DOE & other Experimental/Instrument Collaborations**

Alignment of DUSEL with Physics Priorities

- Long Baseline Neutrinos (LBNE)
- Dark Matter Searches
- Neutrinoless Double Beta Decay
- Relic Neutrinos
- Supernova Neutrinos
- Solar Neutrinos
- Atomic Interferometry
- Gravity Wave Searches
- n-nbar Oscillations



Responses to the January S-4 Call for Proposals (information shared with us)

- Dark Matter Searches
 - ~6 Proposals
- Neutrinoless Double Beta Decay
 - several Proposals
- Long Baseline Neutrinos and Nucleon Decay
 - several Proposals
- Low Background Assay and Material Production
 - at least one Proposal
- Nuclear Astrophysics
 - at least one Proposal
- Solar Neutrinos
 - several Proposals
- Bio/Geo/Eng
 - ~ 8 proposals

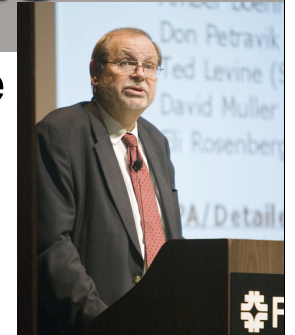
Several experiments had multiple scientific goals

+ Other Physics Proposals

DOE's OHEP Intensity Frontier Plans

DOE OHEP has indicated that it has used P5 Report guidance in the development of its budgets and strategic plan

- In particular, for the development of world-leading neutrino program comprised of a large, long-baseline underground detector and an intense neutrino beam



OHEP is putting in place a process to implement this proposed program (i.e.; follow DOE Order 413.3)

- Seek CD-0 approval for a long baseline neutrino oscillation experiment, tentatively in the first quarter of FY09
- Name a lead laboratory (Fermilab) to develop a conceptual design, explore the alternatives and risks, and establish preliminary cost ranges and schedule
- Support collection of information (e.g.; issues/cost of large excavations)
- Support R&D for proposed elements in the proposed plan
- Seek partners to enhance the scientific reach/scope of the experiment

Since June, DOE (OHEP & ONP) and NSF have been developing a framework for coordination of a joint nuclear and particle physics program at an underground laboratory

- OHEP, ONP, and NSF will coordinate the experimental program through a Joint Oversight Group (JOG) which will hold an inaugural meeting this December.

South Dakota and Sanford Lab Participation in Preparing for DUSEL

- Major Financial Support from the State of South Dakota
 - \$45M from State (HUD grant and General Fund)
 - \$70M from Philanthropic Donation (T. Denny Sanford)
 - Owns the Property (Donation from Barrick)
- Partnership to “achieve DUSEL”
- DUSEL assimilates Sanford Lab at MREFC Construction
- Facility Work Initiated (Site Preparation and Risk Reduction)
 - Rehabilitation of Surface and Underground Infrastructure
 - Lifts & Shafts
 - Pumps
 - Facility Stabilization and Rehabilitation
 - Initial Operations, Environment, and Safety Programs
 - Early Science Program
 - Rock Disposal Sites - *Agreement in Principal* with Barrick to use the “Open Cut”, alternative sites identified





Waste Water Treatment

Open Cut

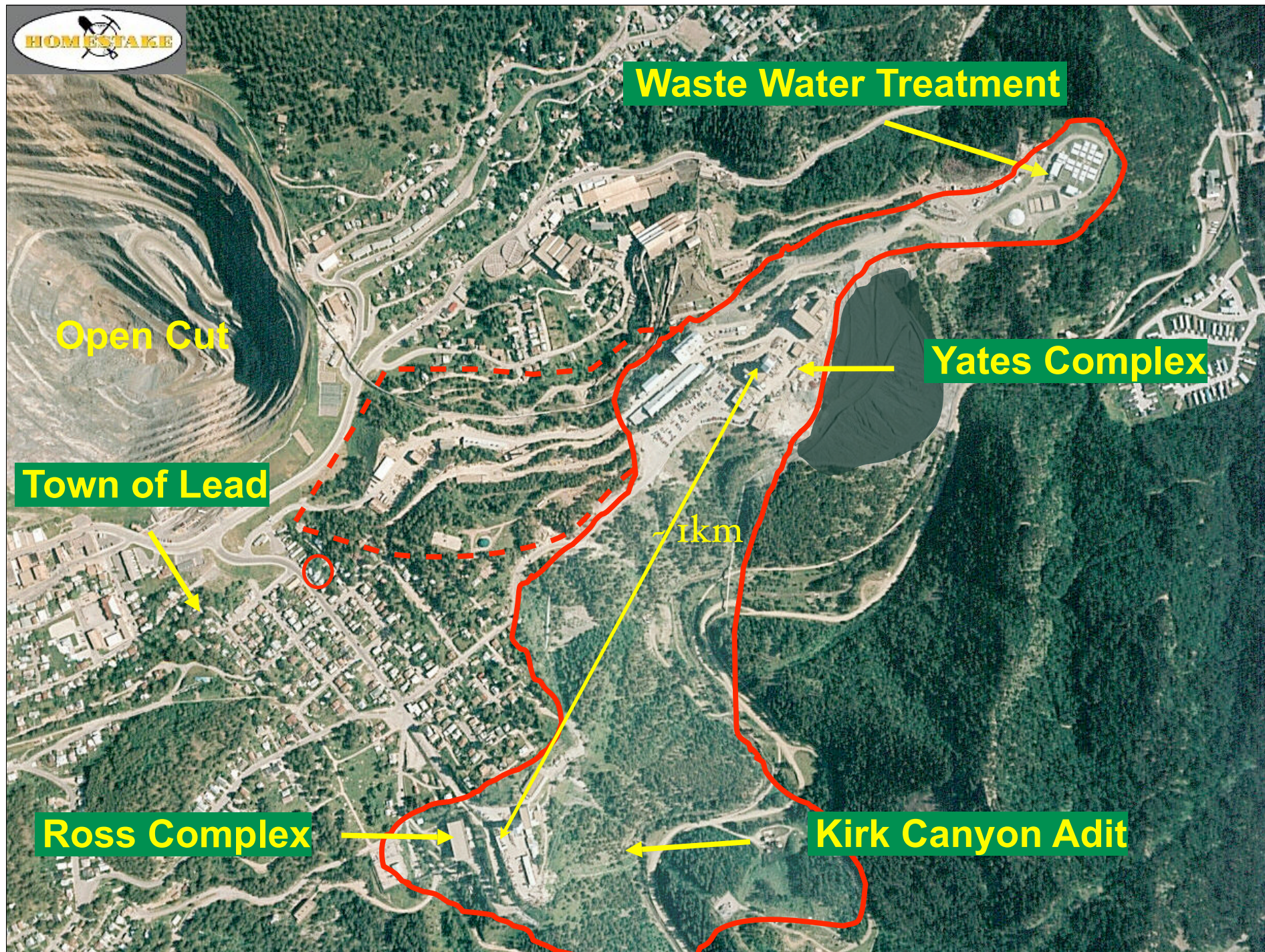
Town of Lead

Yates Complex

~1km

Ross Complex

Kirk Canyon Adit



SDSTA Recent Progress

REHABILITATION OF SHAFTS & HOISTS

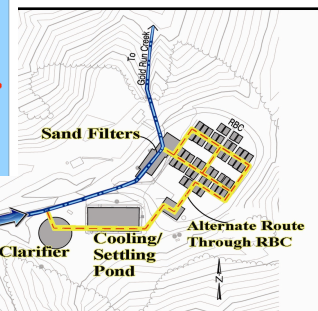
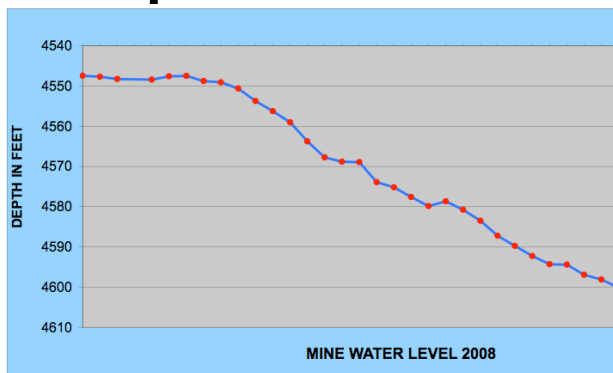
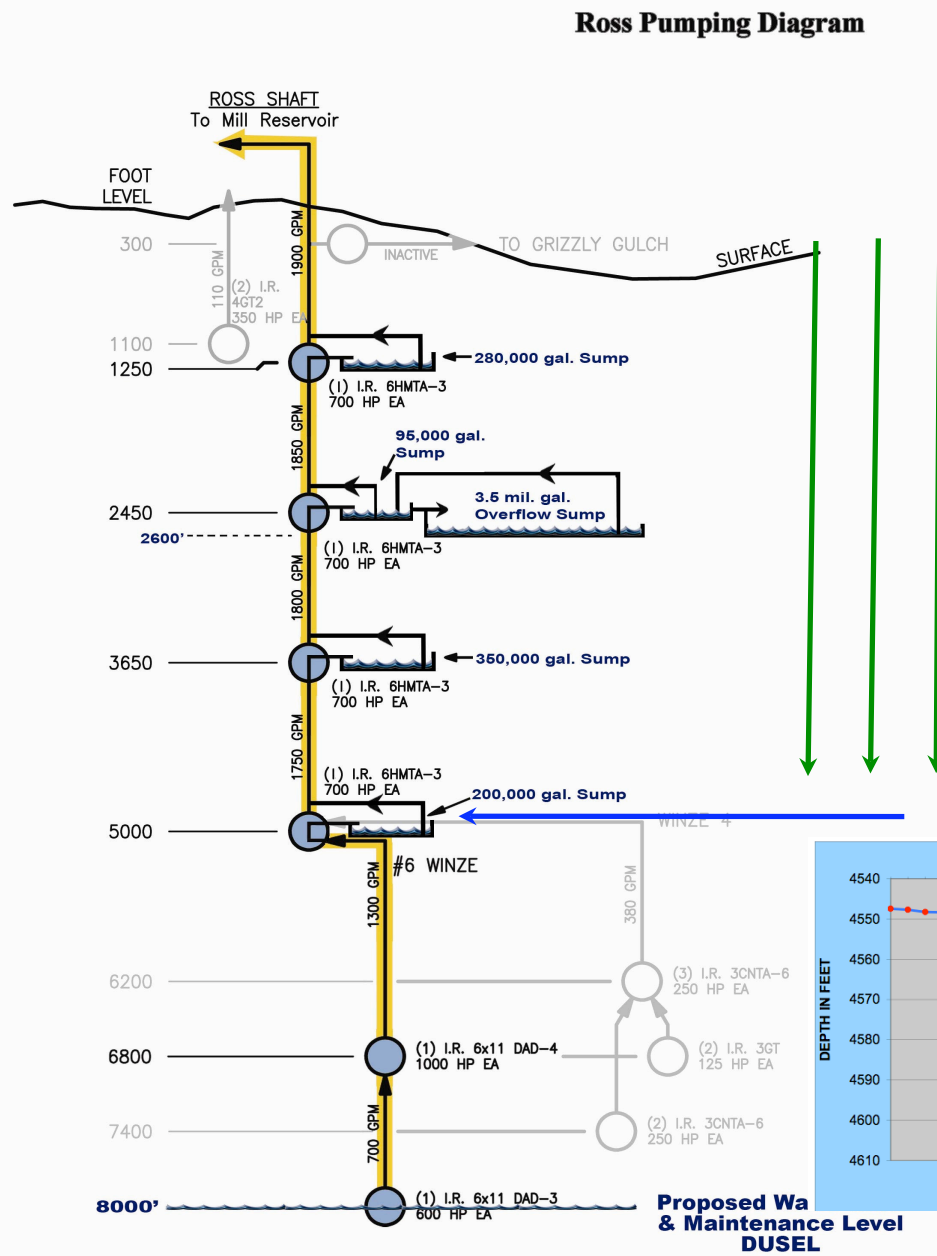
- Ross Shaft rehabilitated to water level. (\$9.2 million)
- Ross Hoist re-certified and operating.
- Yates Shaft rehabilitation in process. (\$9 million bid awarded)

Yates Hoist is re-certified and operating.

Dewatering Homestake: Current Water Levels

Re-entry Efforts, begun July '07

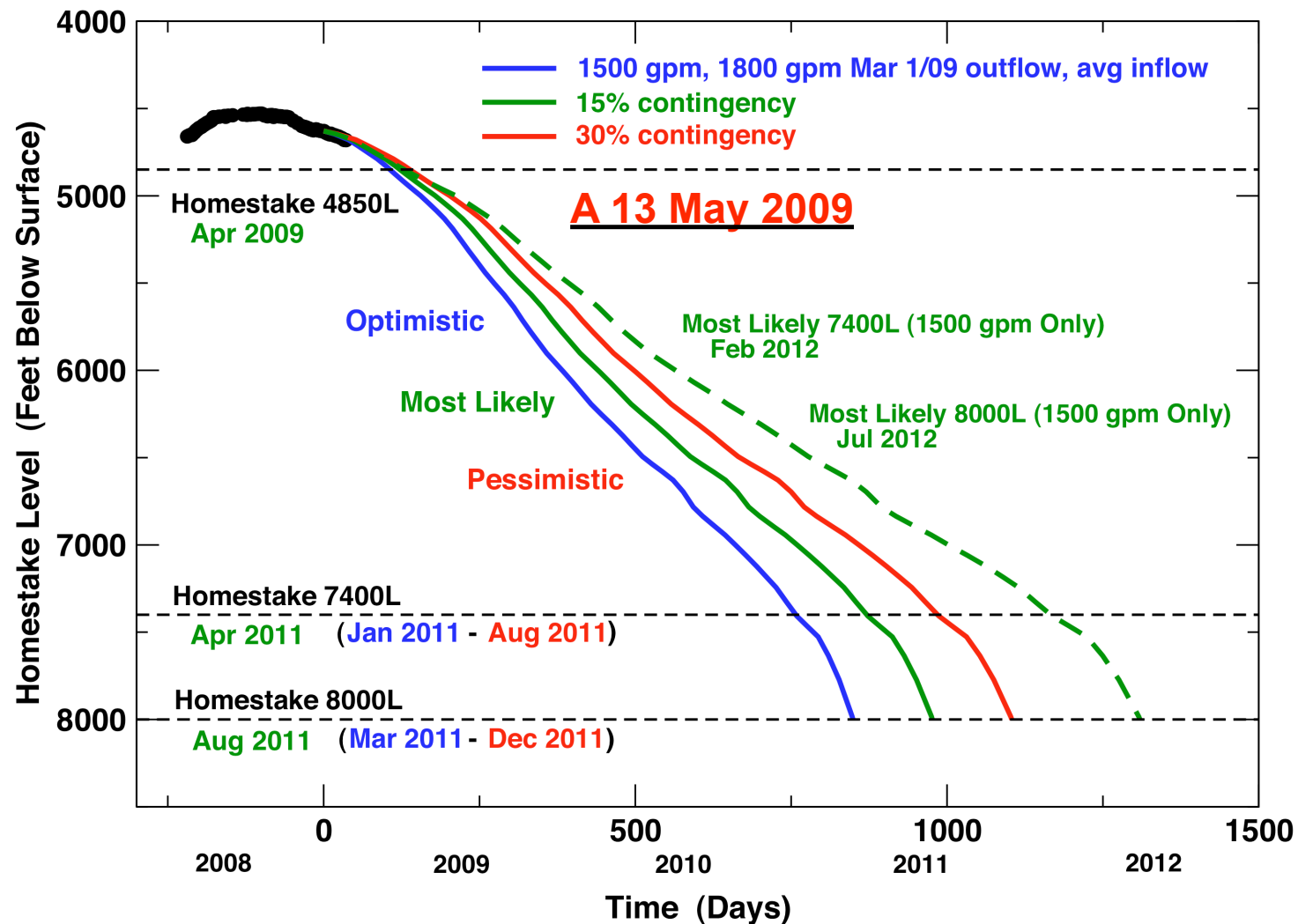
- Ventilation reestablished
- Ross Shaft hoists rehabbed
- Inspected levels and Ross shaft down to ~ 4850
- 4850L achieved May 2009
- Water below the 4920



Dewatering Projection to 7400L and 8000L

DUSEL Dewatering

Projection for the 8000L starting Dec 1/08 based on the Barrick mine model



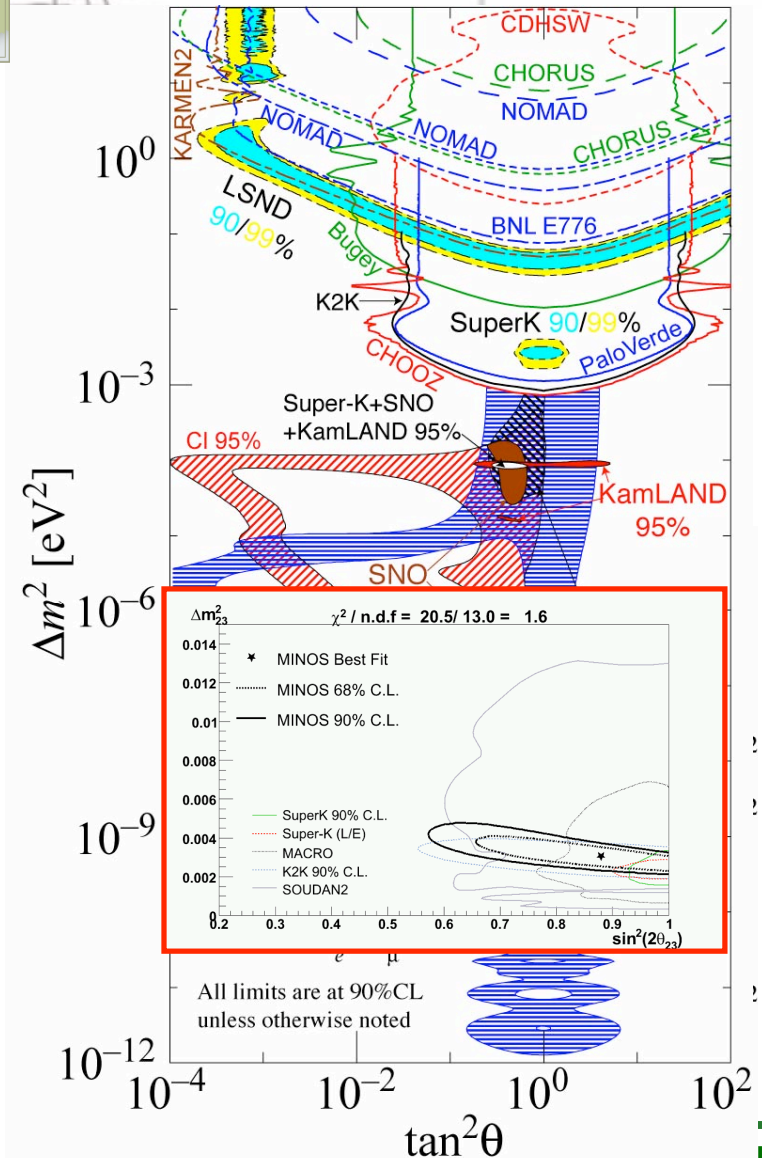
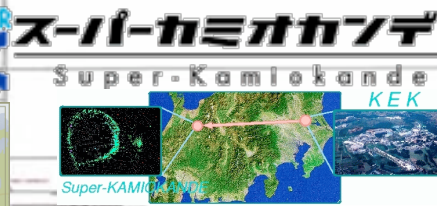




Homestake DUSEL

Outstanding Problems for Neutrinos

- Neutrino Mass Scale
- MNSP Matrix Elements
 - θ_{13} - size of angle
 - θ_{12} - unitarity of matrix
 - Mass hierarchy
 - Verify oscillations
- Sterile Neutrinos?
- CP Violation
- Neutrino Nature
(Dirac or Majorana)



DUSEL's Long Baseline Neutrino Program

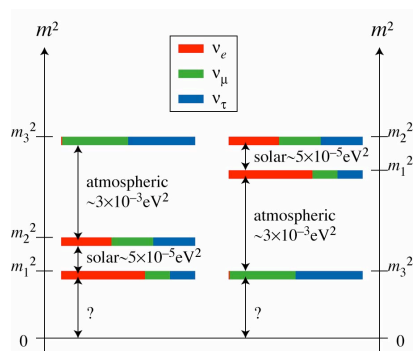
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Super-K
MINOS
K2K
T2K

Chooz
Double Chooz
Daya Bay

SNO
KamLAND
SuperK
BOREXINO

The Mixing Matrix



$$U = \begin{matrix} \text{Atmospheric} \\ \begin{bmatrix} 1 & 0 & 0 \\ 0 & c_{23} & s_{23} \\ 0 & -s_{23} & c_{23} \end{bmatrix} \end{matrix} \times \begin{matrix} \text{Cross-Mixing} \\ \begin{bmatrix} c_{13} & 0 & s_{13}e^{-i\delta} \\ 0 & 1 & 0 \\ -s_{13}e^{i\delta} & 0 & c_{13} \end{bmatrix} \end{matrix} \times \begin{matrix} \text{Solar} \\ \begin{bmatrix} c_{12} & s_{12} & 0 \\ -s_{12} & c_{12} & 0 \\ 0 & 0 & 1 \end{bmatrix} \end{matrix}$$

$$\times \begin{bmatrix} e^{i\alpha_1/2} & 0 & 0 \\ 0 & e^{i\alpha_2/2} & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

$$c_{ij} \equiv \cos \theta_{ij}$$

$$s_{ij} \equiv \sin \theta_{ij}$$

$$\theta_{12} \approx \theta_{\text{sol}} \approx 35^\circ, \quad \theta_{23} \approx \theta_{\text{atm}} \approx 37-53^\circ, \quad \theta_{13} \lesssim 10^\circ$$

Majorana ~~CP~~
phases

δ would lead to $P(\bar{\nu}_\alpha \rightarrow \bar{\nu}_\beta) \neq P(\nu_\alpha \rightarrow \nu_\beta)$. ~~CP~~

But note the crucial role of $s_{13} \equiv \sin \theta_{13}$.

Adapted from Boris Kayser

Physics Motivations: Long Baseline Neutrinos

Accelerator ($\bar{\nu}$) Oscillation Probabilities

With $\alpha \equiv \Delta m_{21}^2 / \Delta m_{31}^2$, $\Delta \equiv \frac{\Delta m_{31}^2 L}{4E}$, and $x \equiv \frac{2\sqrt{2}G_F N_e E}{\Delta m_{31}^2}$ —

Matter effects

$$P[\nu_\mu \rightarrow \nu_e] \equiv \sin^2 2\theta_{13} T_1 - \alpha \sin 2\theta_{13} T_2 + \alpha \sin 2\theta_{13} T_3 + \alpha^2 T_4 ;$$

CP Odd

$$T_1 = \sin^2 \theta_{23} \frac{\sin^2[(1-x)\Delta]}{(1-x)^2}, \quad T_2 = \sin \delta \sin 2\theta_{12} \sin 2\theta_{23} \sin \Delta \frac{\sin(x\Delta)}{x} \frac{\sin[(1-x)\Delta]}{(1-x)},$$

CP Even

$$T_3 = \cos \delta \sin 2\theta_{12} \sin 2\theta_{23} \cos \Delta \frac{\sin(x\Delta)}{x} \frac{\sin[(1-x)\Delta]}{(1-x)}, \quad T_4 = \cos^2 \theta_{23} \sin^2 2\theta_{12} \frac{\sin^2(x\Delta)}{x^2}$$

$$P[\bar{\nu}_\mu \rightarrow \bar{\nu}_e] = P[\nu_\mu \rightarrow \nu_e] \text{ with } \delta \rightarrow -\delta \text{ and } x \rightarrow -x.$$

(Cervera *et al.*, Freund, Akhmedov *et al.*)

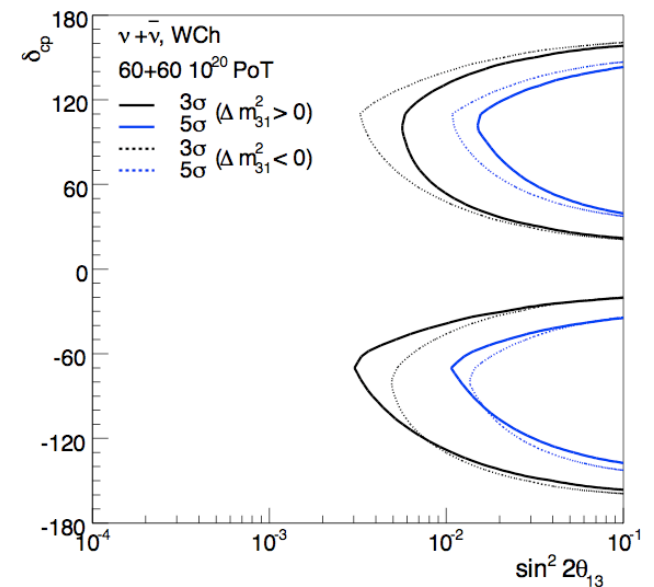
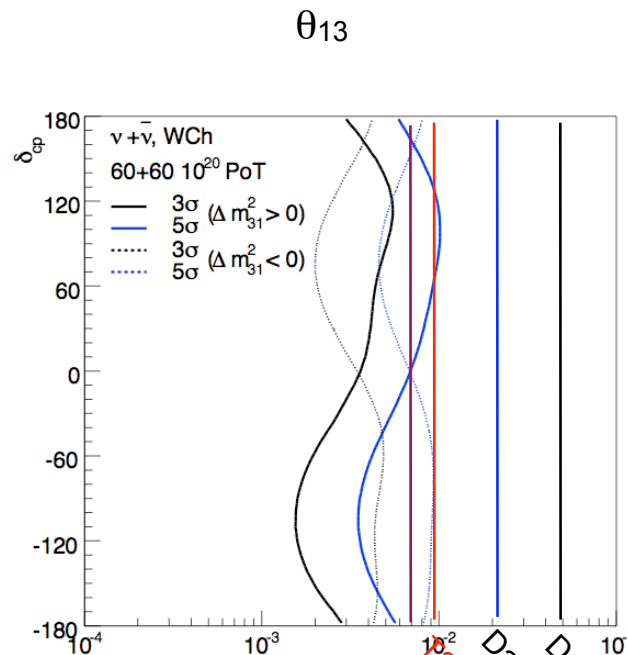
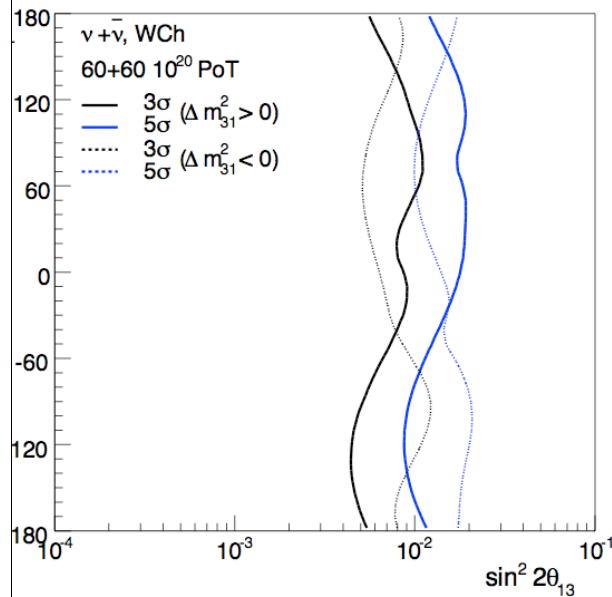
Physics with 300-kt Water Cherenkov Detector & 2 MW Beams @ 120 GeV 3 years each $\nu + \bar{\nu}$

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Mass hierarchy
 θ_{13}
 CP violation

Exclusion of CP Violation

Mass Hierarchy



Double Chooz 2012
 Daya Bay 2013
 NOVA 2017
 12K 2012
 100kt LAr DUSEL

60x10²⁰ POT each
 1kt LAr \approx 3kt H₂O

Homestake DUSEL

Program: FNAL to Homestake ~ 1290 km

FNAL (L~1290 km) 700 kW
@ 120 GeV $\rightarrow 6 \times 10^{20}$ POT /yr
by ~ 2012

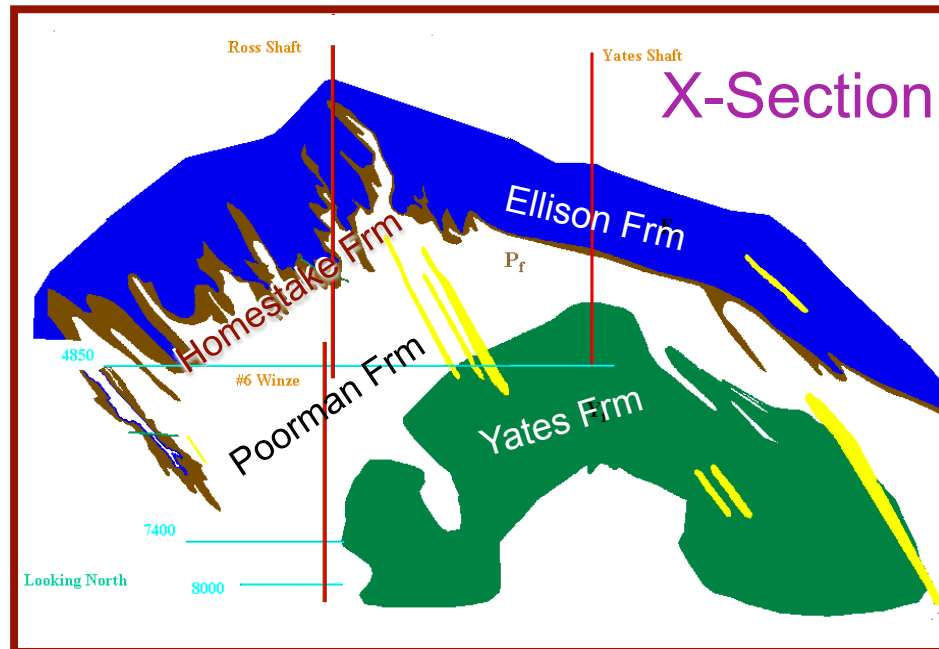


Then Project X: 2.3 MW
@ 60 - 120 GeV as early as 2016

Homestake DUSEL

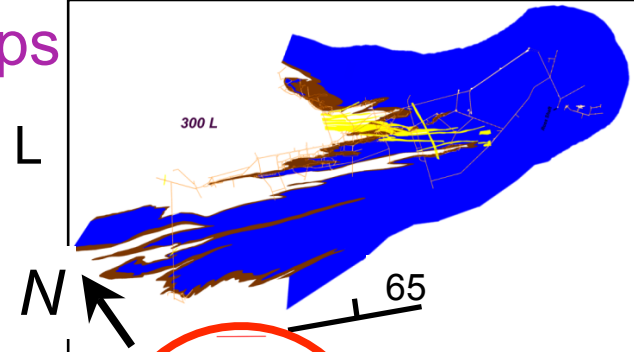
Conditions: Geology

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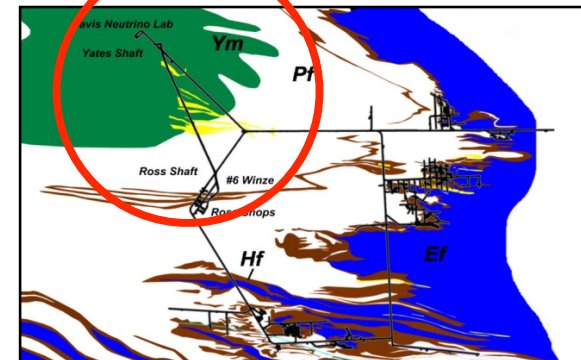


Maps

300 L



4850 L

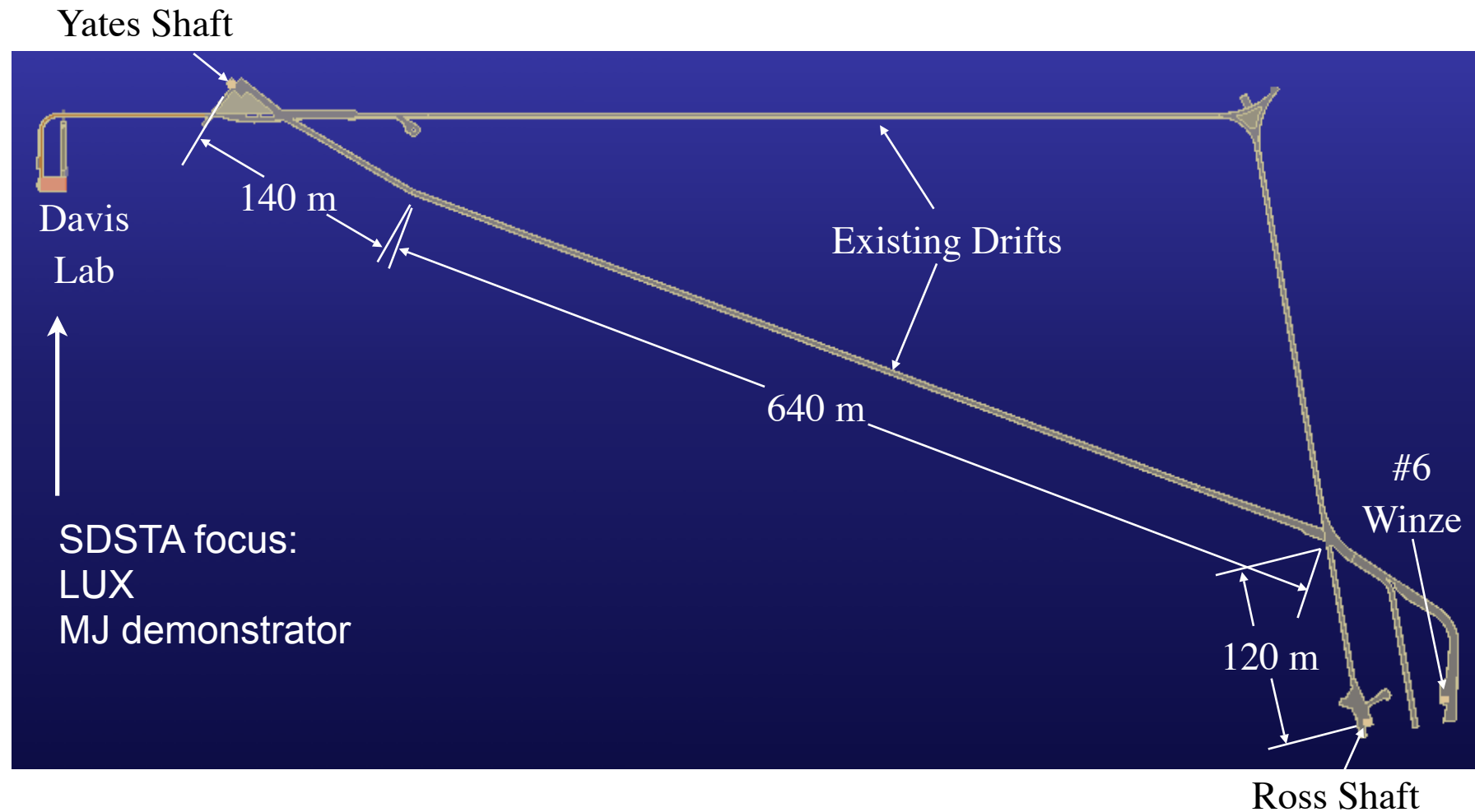


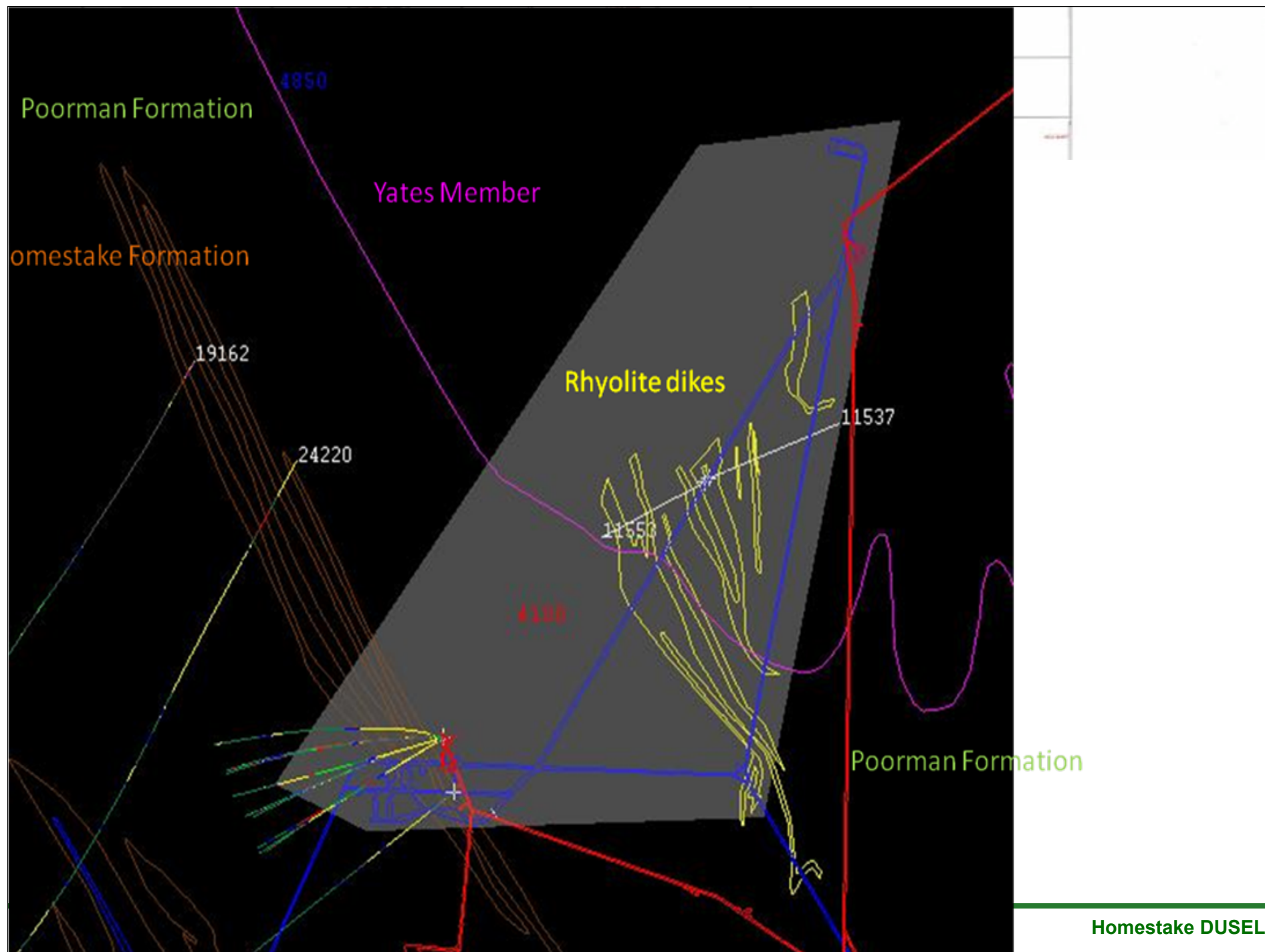
7400 L

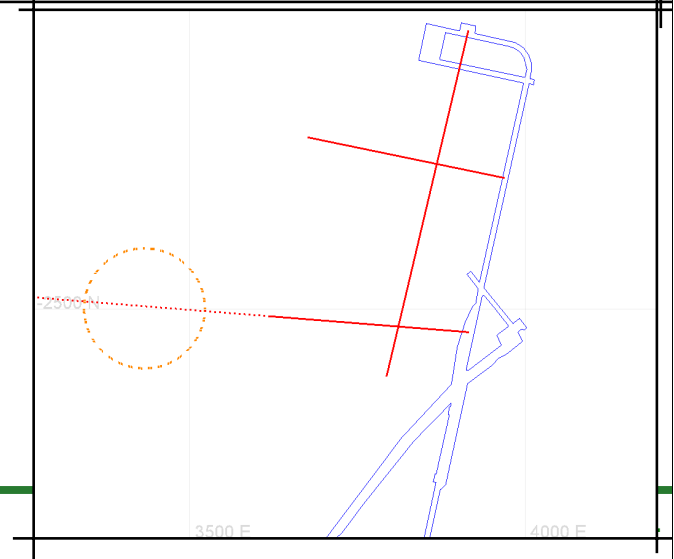
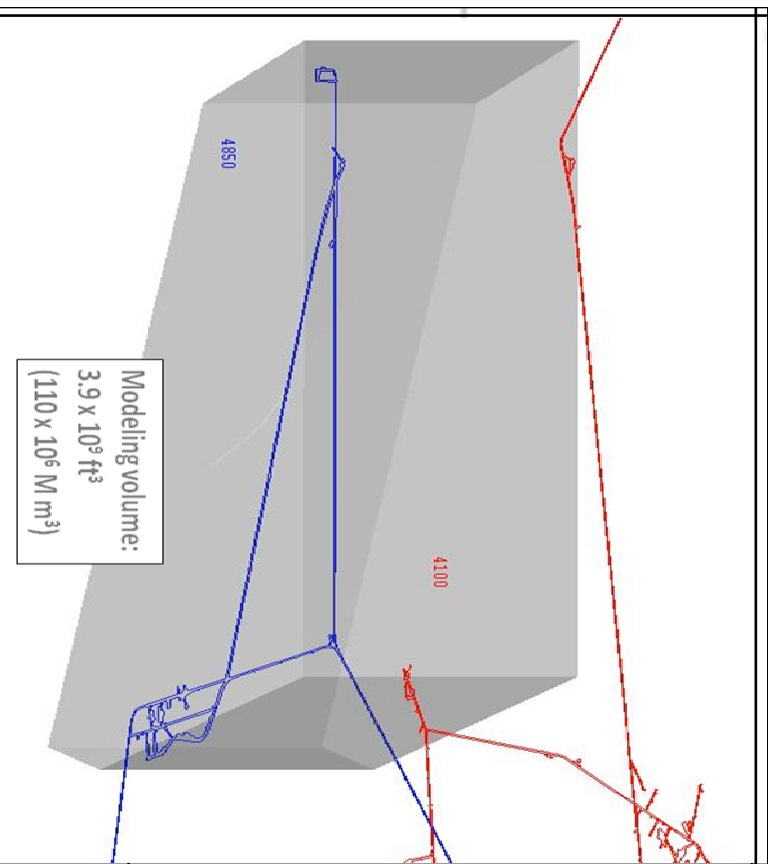
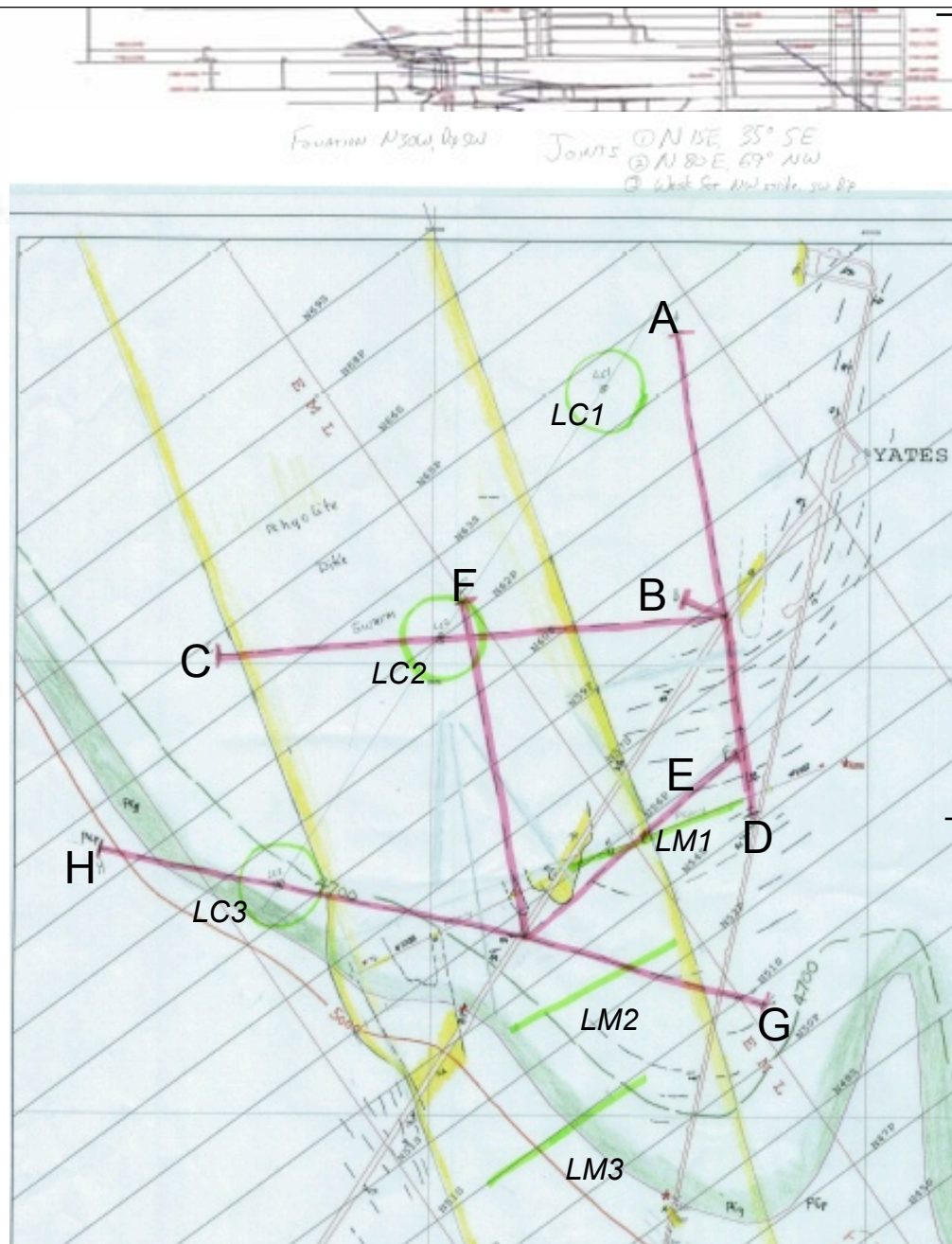


- Subsurface geology is complex, well-known.
- Structure: Isoclinal folds, shear zones, general dip 65° NE. Later joint set.
- Wide range of rock compositions at every level.

Existing Development at 4850L Campus (Plan View)



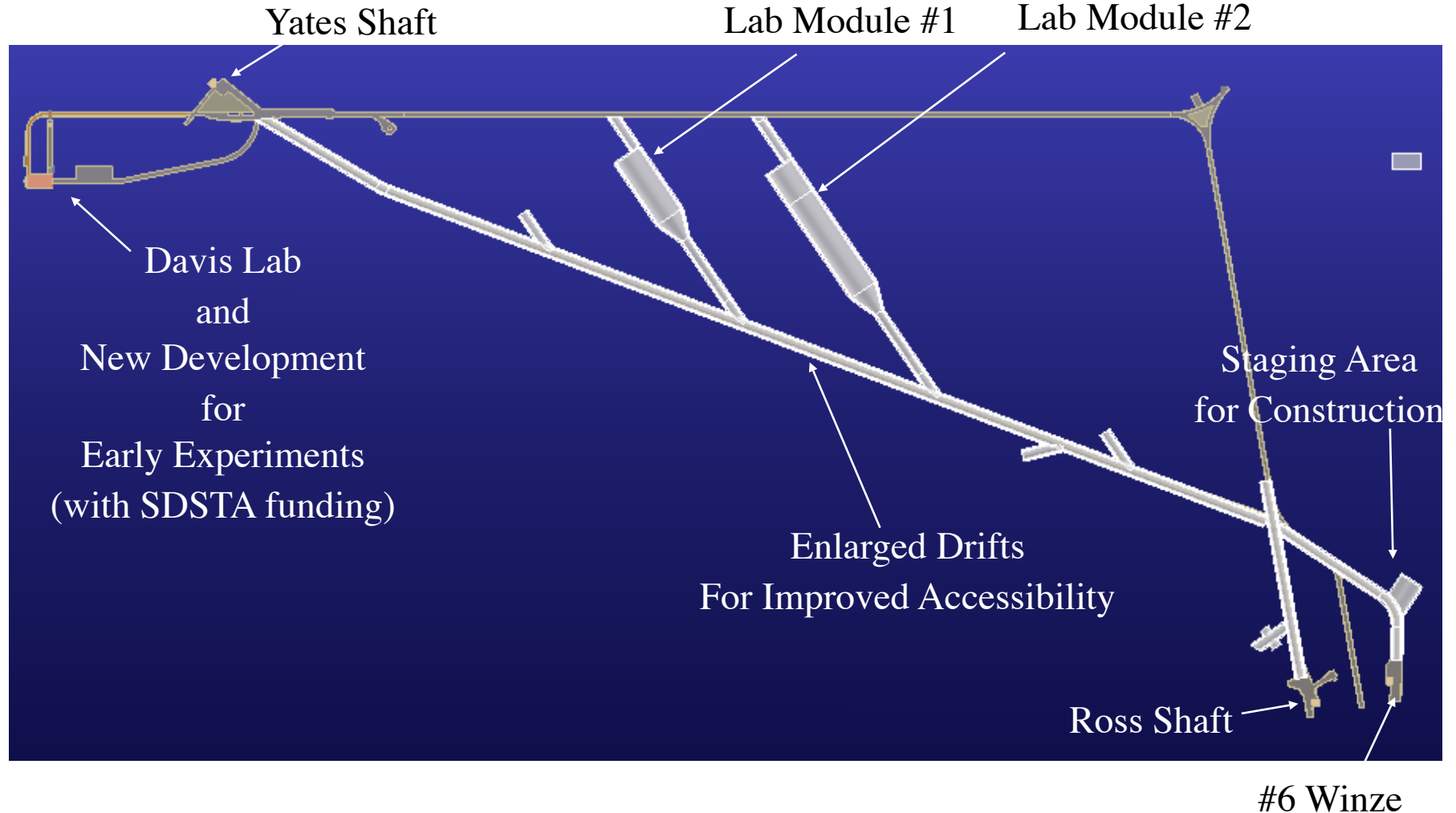




Sequential Development of Space at 4850L: Two Lab Modules for DUSEL Experiments (Plan View)

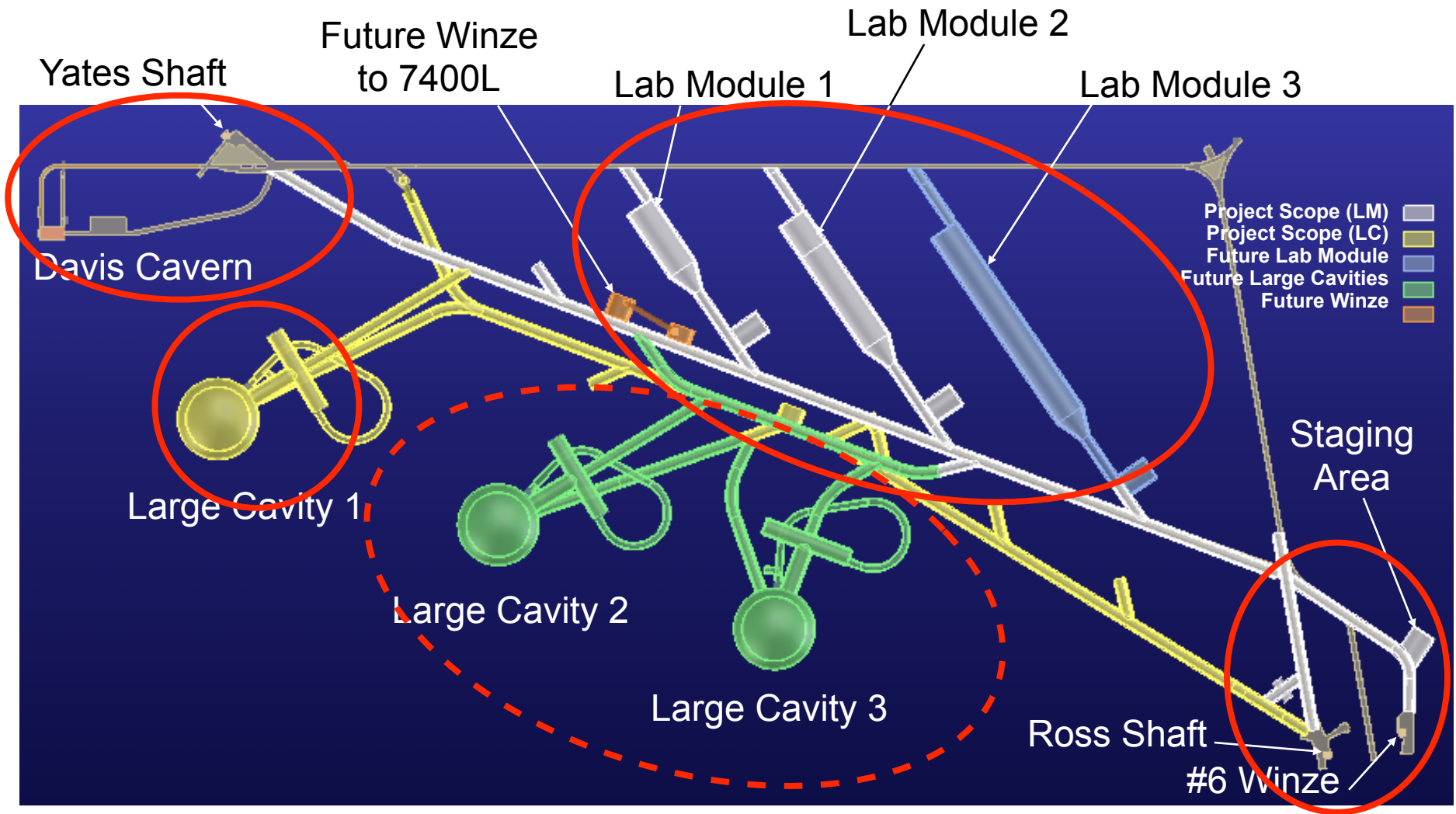
LONGSECTION OF THE HOMESTAKE MINE

Standard Lab Modules: ~20m x 20m x 50-100m long
Lab Module #1 Lab Module #2



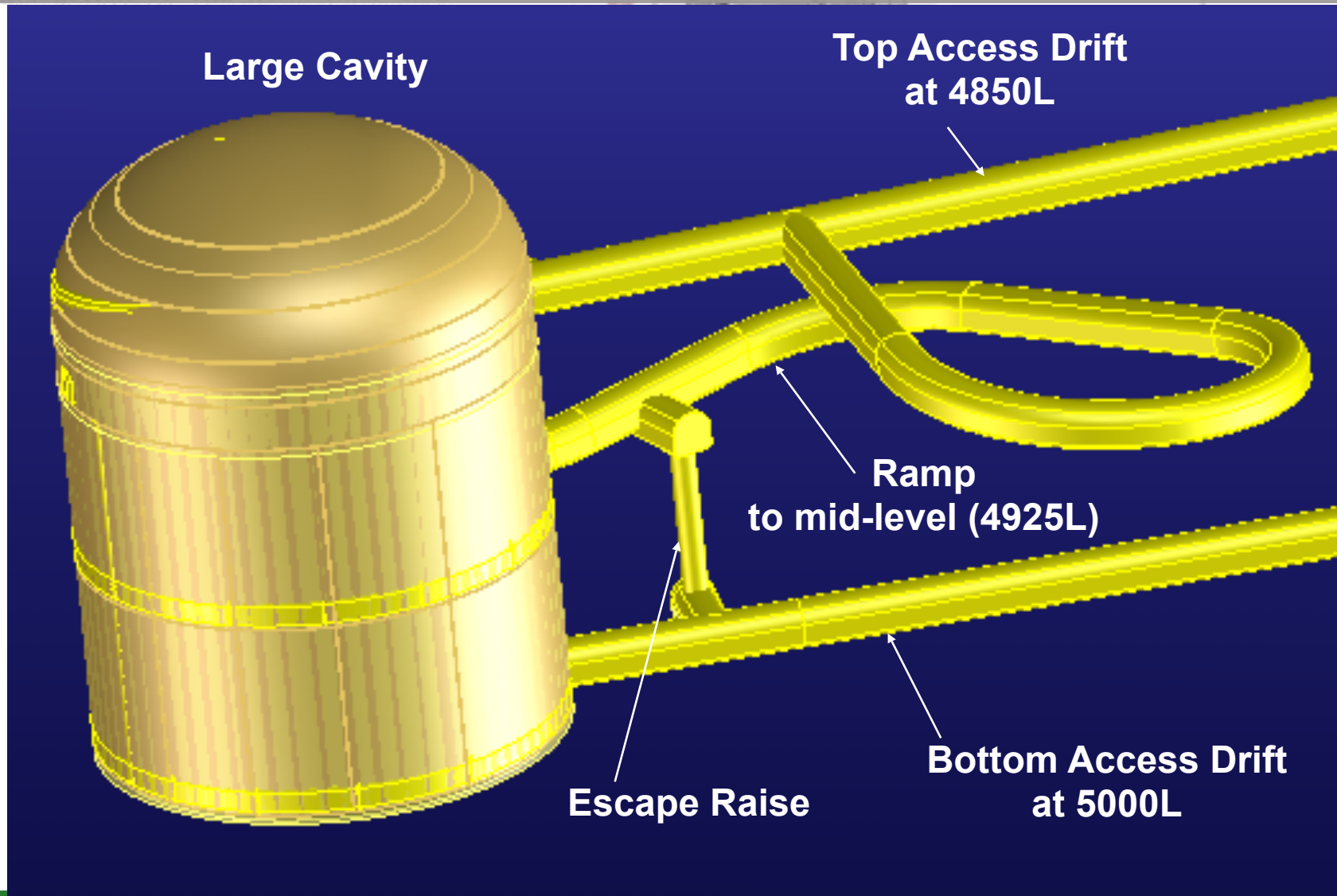
DUSEL 4850 Level Development:

3 Lab Modules, 1 Large Cavity & Future Winze, Plan View
Future Scope within dotted lines



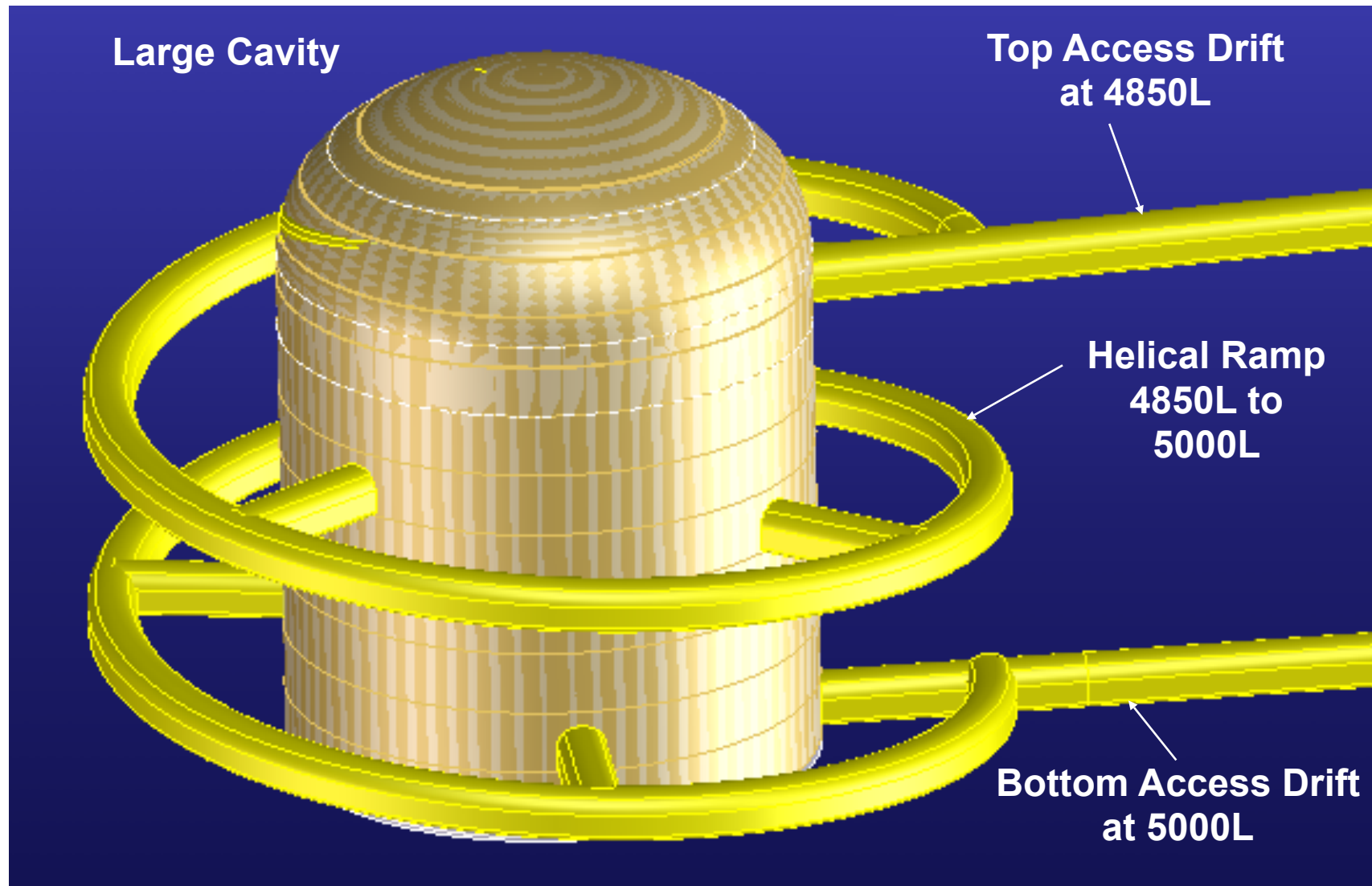
Large Cavity, Bulk Excavation Method

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Large Cavity, Benching Excavation Method

LONGSECTION OF THE HOMESTAKE MINE



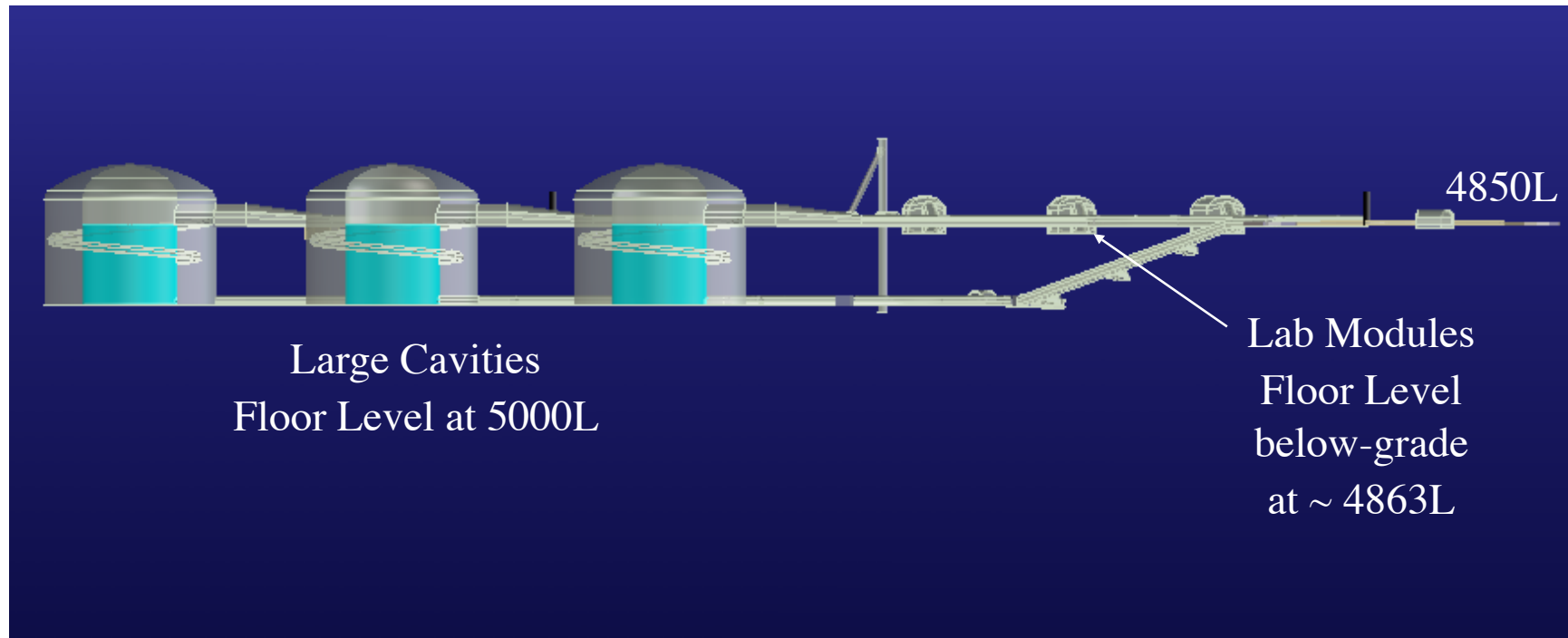
DUSEL Large Cavity in comparison to the ALS at LBNL





4850L Preliminary Layout

Elevation View with 3 Lab Modules and 3 Large Cavities



Current Geotechnical work funded in 2009 will assess initial sites for further investigations

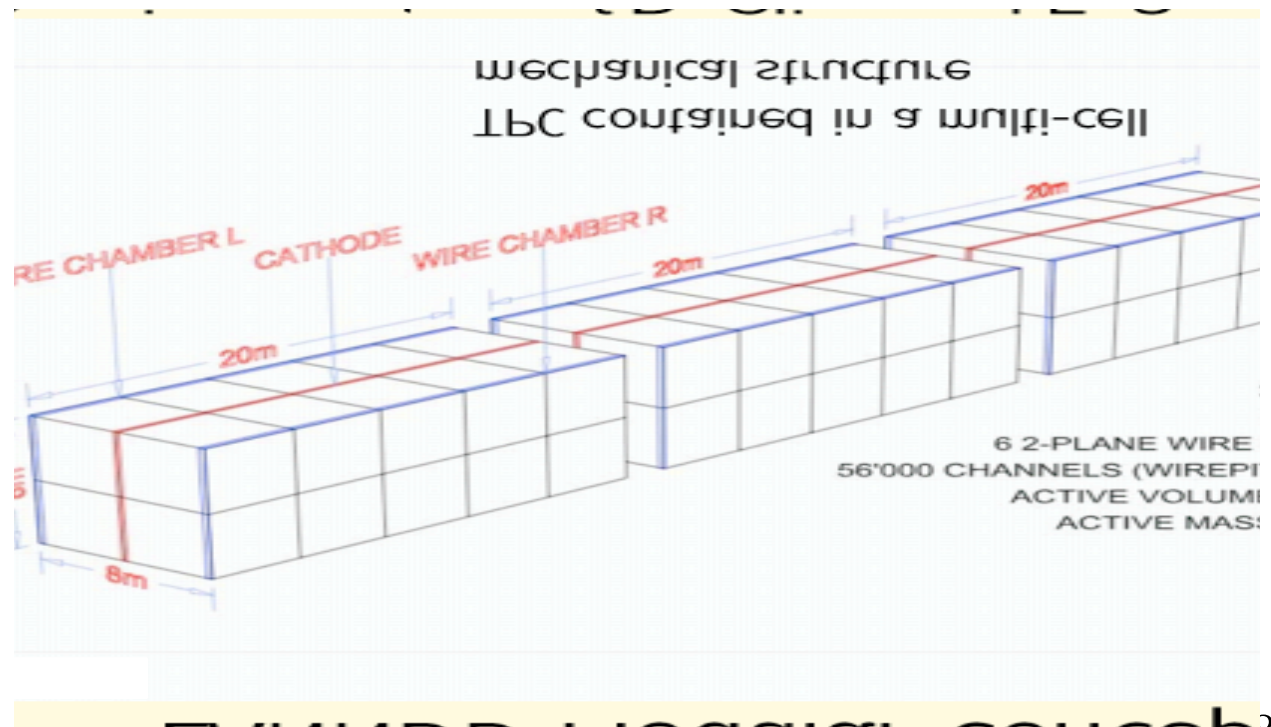
Subsequent design will advance the design of the lab modules and large cavities, including excavation design, rock disposal, infrastructure requirements

Next step beyond MicroBooNE, 5 + 15-25ktons at DUSEL
(en route to total detector mass of ~50ktons)

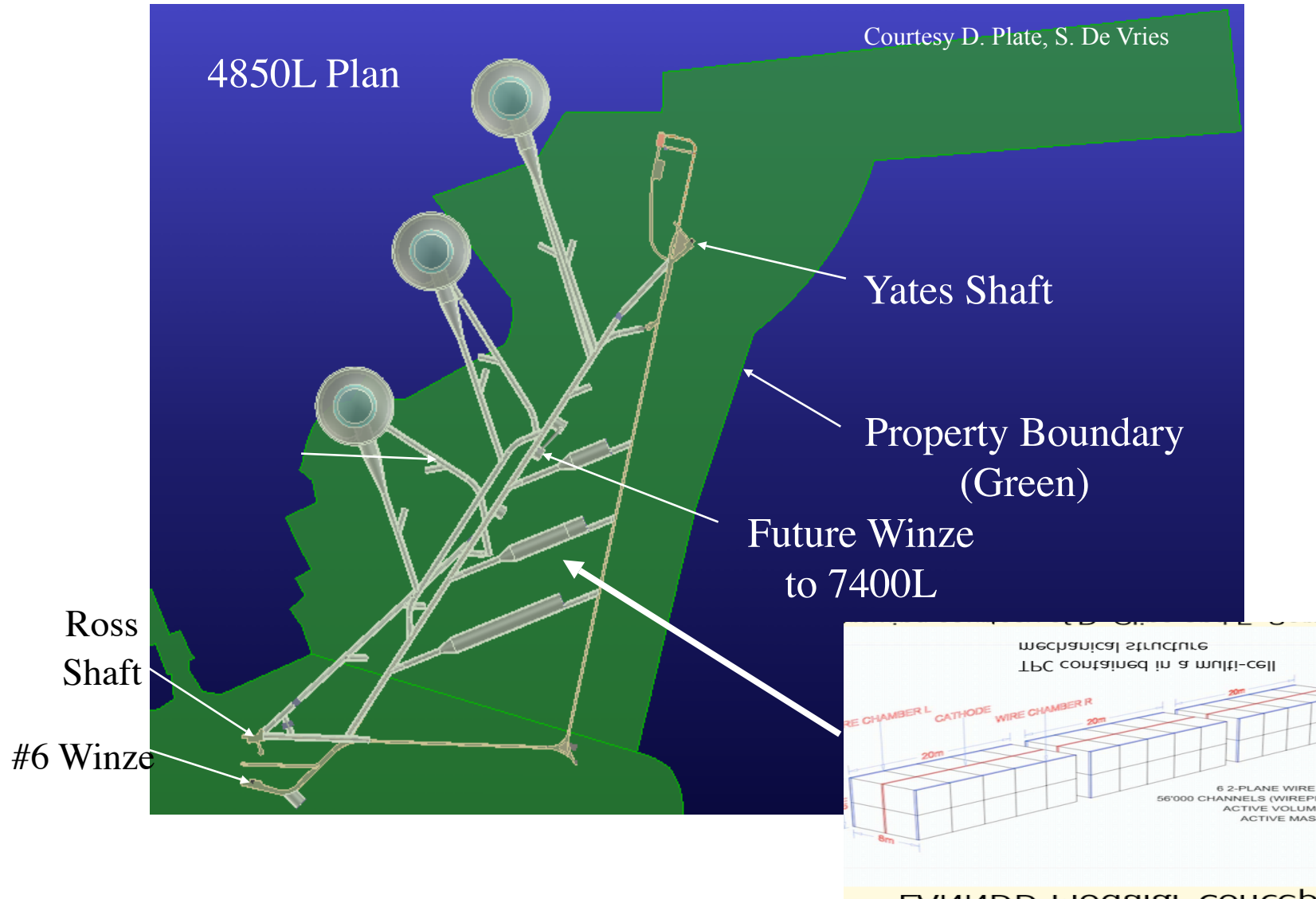
Start with 5kton, with larger modules beyond

- Good physics reach
- sized well for ISE at DUSEL – get started soon!
- Appropriate step in size beyond MicroBooNE
technically a reasonable step.....

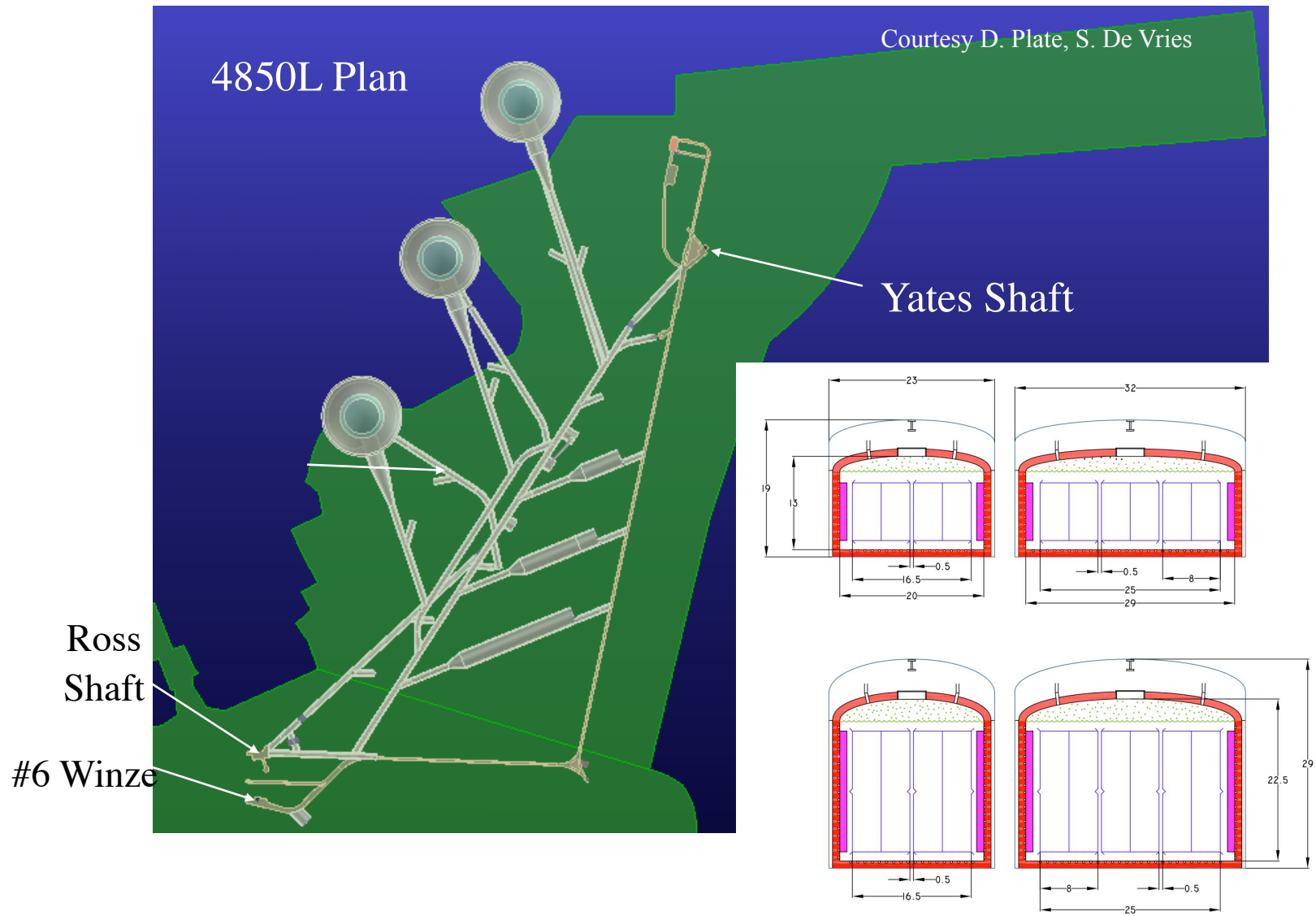
5kton
Concept
(D. Cline,
F. Sergiampietri)



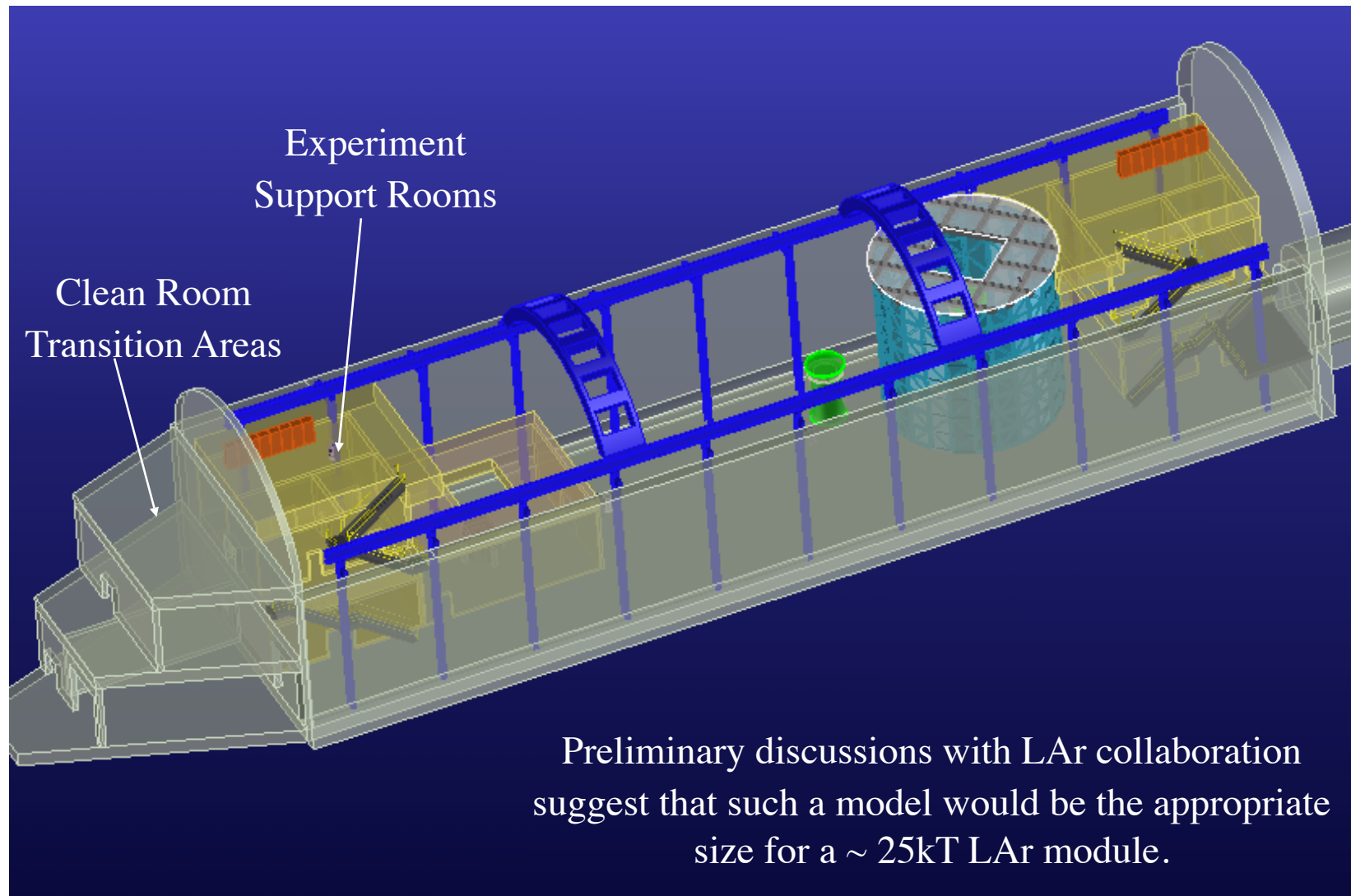
Underground caverns for DUSEL experiments 5kton fits in the largest of the caverns planned for the ISE



Further excavation for modules beyond the 5kton needed

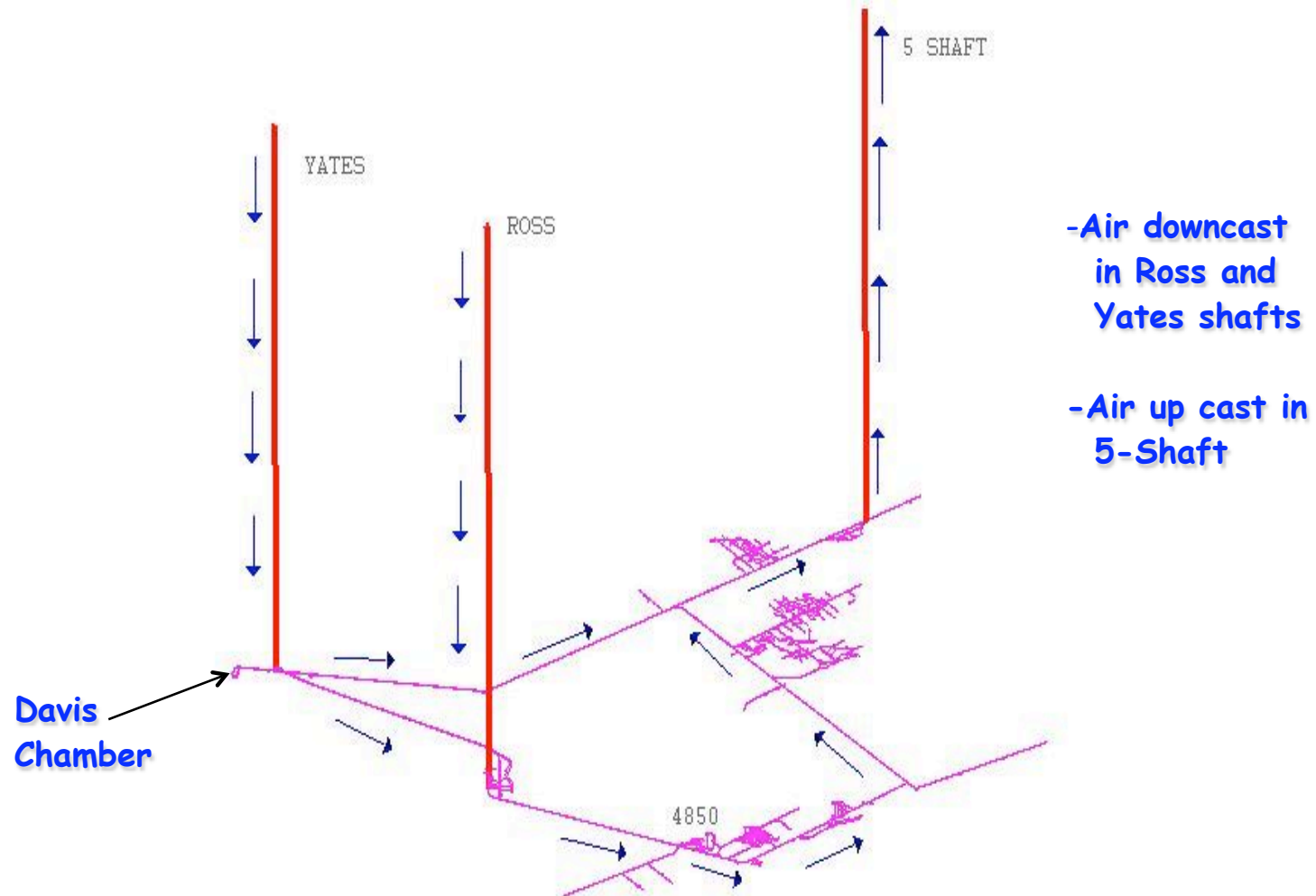


Conceptual layout of laboratory space

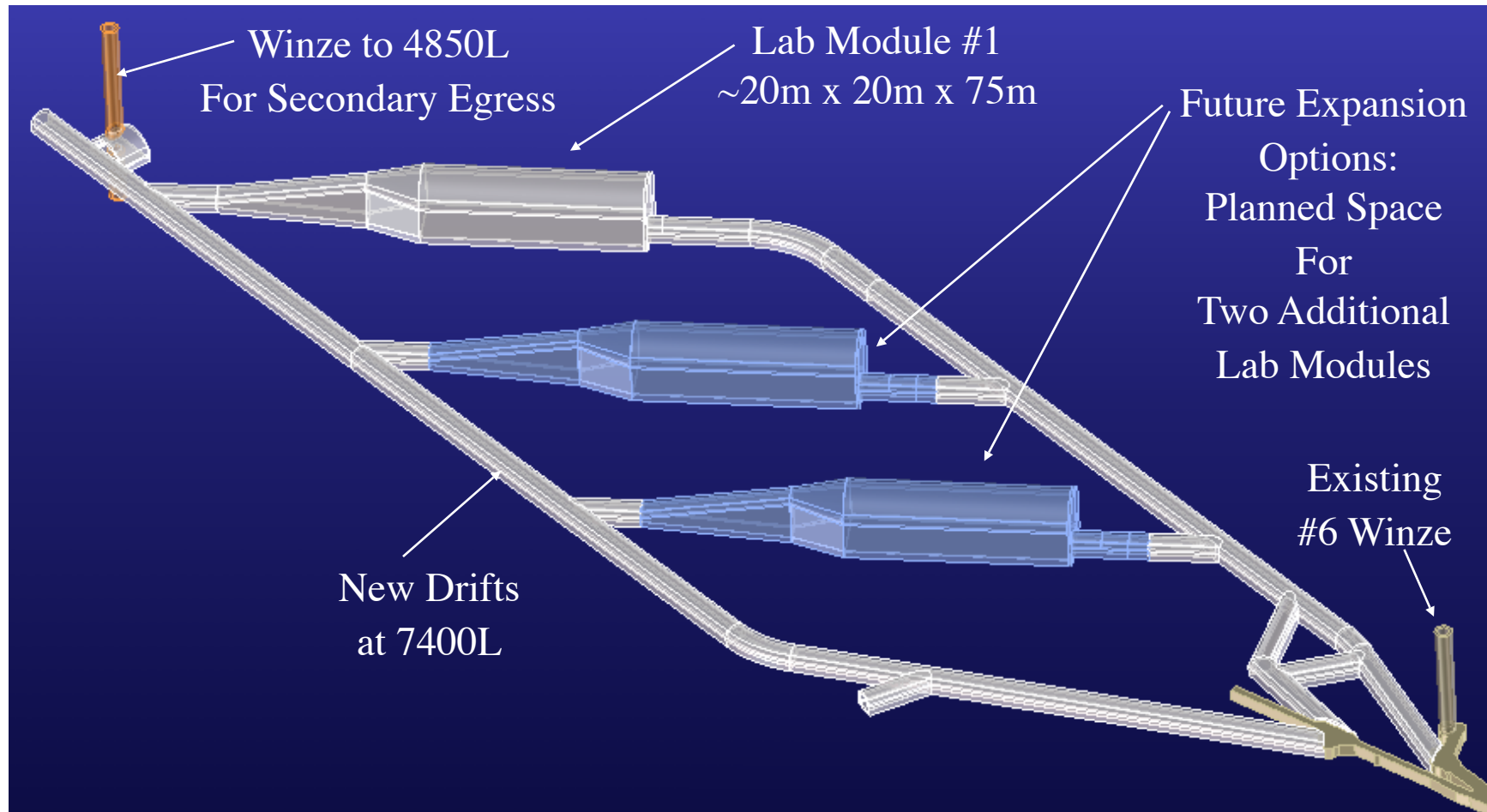


Ventilation on the 4850L

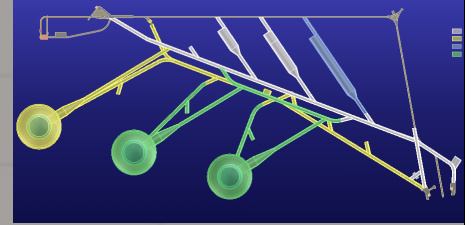
LONGSECTION OF THE HOMESTAKE MINE



Development at 7400 Level for Deep Campus Preliminary Layout (Plan View)



DUSEL Attributes



- DUSEL will be a Critical Facility with Unparalleled Attributes:
 - Large excavations to host a variety of experimental programs
 - Long term, non-competed access to site
 - Access to unusual depth for important initiatives in deep science
 - Broad access to a large volume of low radioactivity rock
- A Facility Enabling World-class Science and Engineering in:
 - Physics
 - Biology
 - Geosciences
 - Engineering
- A Facility Addressing Questions with Significant Societal Impact:
 - Underground Construction
 - Energy Sources and Sustainability
 - Resource Recovery and Sustainability
 - Mitigating Natural Hazards
 - **Education and Public Outreach**

